A

THE INSTITUTION

OF

MECHANICAL ENGINEERS.

ESTABLISHED 1847.

PROCEEDINGS.

1905.

PARTS 1–2.

PUBLISHED BY THE INSTITUTION,

STOREY'S GATE, ST. JAMES'S PARK, WESTMINSTER, S.W.

CONTENTS.

1905.

PARTS 1–2.

The Institution of Mechanical Engineers.

PAST-PRESIDENTS.

George Stephenson, 1847–48. (*Deceased* 1848.)

Robert Stephenson, F.R.S., 1849–53. (*Deceased* 1859.)

Sir William Fairbairn, Bart., LL.D., F.R.S., 1854–55. (*Deceased* 1874.)

Sir Joseph Whitworth, Bart., D.C.L., LL.D., F.R.S., 1856–57, 1866. (*Deceased* 1887.)

John Penn, F.R.S., 1858–59, 1867–68. (*Deceased* 1878.)

James Kennedy, 1860. (*Deceased* 1886.)

The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S., 1861–62, 1869. (*Deceased* 1900.)

Robert Napier, 1863–65. (*Deceased* 1876.)

John Ramsbottom, 1870–71. (*Deceased* 1897.)

Sir William Siemens, D.C.L., LL.D., F.R.S., 1872–73. (*Deceased* 1883.)

Sir Frederick J. Bramwell, Bart., D.C.L., LL.D., F.R.S., 1874–75 (*Deceased* 1903.)

Thomas Hawksley, F.R.S., 1876–77. (*Deceased* 1893.)

John Robinson, 1878–79. (*Deceased* 1902.)

Edward A. Cowper, 1880–81. (*Deceased* 1893.)

Percy G. B. Westmacott, 1882–83.

Sir Lowthian Bell, Bart., LL.D., F.R.S., 1884. (*Deceased* 1904.)

Jeremiah Head, 1885–86. (*Deceased* 1899.)

Sir Edward H. Carbutt, Bart., 1887–88.

Charles Cochrane, 1889. (*Deceased* 1898.)

Joseph Tomlinson, 1890–91. (*Deceased* 1894.)

Sir William Anderson, K.C.B., D.C.L., F.R.S., 1892–93. (*Deceased* 1898.)

Professor Alexander B. W. Kennedy, LL.D., F.R.S., 1894–95.

E. Windsor Richards, 1896–97.

Samuel Waite Johnson, 1898.

Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S., 1899–1900.

William H. Maw, 1901–02.

J. Hartley Wicksteed, 1903–04.

The Institution of Mechanical Engineers.

OFFICERS.

1905.

PRESIDENT.

Edward P. Martin, ... Abergavenny.

PAST-PRESIDENTS.

Sir Edward H. Carbutt, Bart., ... London.
Samuel Waite Johnson, ... Nottingham.
Professor Alexander B. W. Kennedy, LL.D., F.R.S., .. London.
William H. Maw, ... London.
E. Windsor Richards, ... Caerleon.
Percy G. B. Westmacott, ... Ascot.
Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S., .. London.
J. Hartley Wicksteed, ... Leeds.

VICE-PRESIDENTS.

John A. F. Aspinall, ... Manchester.
Edward B. Ellington, ... London.
Arthur Keen, ... Birmingham.
Sir William T. Lewis, Bart., ... Aberdare.
T. Hurry Riches, ... Cardiff.
A. Tannett-Walker, ... Leeds.

MEMBERS OF COUNCIL.

Sir Benjamin Baker, K.C.B., K.C.M.G., LL.D., D.Sc., F.R.S., London.
Sir J. Wolfe Barry, K.C.B., LL.D., F.R.S., ... London.
Henry Chapman, ... London.
George J. Churchward, ... Swindon.
Henry Davey, ... London.
William Dean, ... Folkestone.
H. Graham Harris, ... London.
Edward Hopkinson, D.Sc., ... Manchester.
Henry A. Ivatt, ... Doncaster.
Henry Lea, ... Birmingham.
Michael Longridge, ... Manchester.
James Mansergh, F.R.S., ... London.
Henry D. Marshall, ... Gainsborough.
The Right Hon. William J. Pirrie, LL.D., ... Belfast.
Sir Thomas Richardson, ... Hartlepool.
John F. Robinson, ... London.
Mark H. Robinson, ... Rugby.
John W. Spencer, ... Newcastle-on-Tyne.
Sir John I. Thornycroft, LL.D., F.R.S., ... London.
John Tweedy, ... Newcastle-on-Tyne.
Henry H. West, ... Liverpool.

HON. TREASURER.

Harry Lee Millar.

AUDITOR.

Robert A. McLean, F.C.A.

SECRETARY.

Edgar Worthington,

The Institution of Mechanical Engineers,

Storey's Gate, St. James's Park, Westminster, S.W.

Telegraphic address:—*Mech, London.* Telephone:—*Westminster*, 264.

THE INSTITUTION OF MECHANICAL ENGINEERS.

Memorandum of Association.

AUGUST 1878.

1st. The name of the Association is "THE INSTITUTION OF MECHANICAL ENGINEERS."

2nd. The Registered Office of the Association will be situate in England.

3rd. The objects for which the Association is established are :—

(A.) To promote the science and practice of Mechanical Engineering and all branches of mechanical construction, and to give an impulse to inventions likely to be useful to the Members of the Institution and to the community at large.

(B.) To enable Mechanical Engineers to meet and to correspond, and to facilitate the interchange of ideas respecting improvements in the various branches of mechanical science, and the publication and communication of information on such subjects.

(C.) To acquire and dispose of property for the purposes aforesaid.

(D.) To do all other things incidental or conducive to the attainment of the above objects or any of them.

4th. The income and property of the Association, from whatever source derived, shall be applied solely towards the promotion of the objects of the Association as set forth in this Memorandum of Association, and no portion thereof shall be paid or transferred directly or indirectly, by way of dividend, bonus, or otherwise howsoever, by way of profit to the persons who at any time are or have been Members of the Association, or to any of them, or to any person claiming through any of them: Provided that nothing herein contained shall prevent the payment in good faith of remuneration to any officers or servants of the Association, or to any Member of the Association, or other person, in return for any services rendered to the Association, or prevent the giving of privileges to the Members of the Association in attending the meetings of the Association, or prevent the borrowing of money (under such powers as the Association and the Council thereof may possess) from any Member of the Association, at a rate of interest not greater than five per cent. per annum.

5th. The fourth paragraph of this Memorandum is a condition on which a licence is granted by the Board of Trade to the Association in pursuance of Section 23 of the Companies Act 1867. For the purpose of preventing any evasion of the terms of the said fourth paragraph, the Board of Trade may from time to time, on the application of any Member of the Association, impose further conditions, which shall be duly observed by the Association.

6th. If the Association act in contravention of the fourth paragraph of this Memorandum, or of any such further conditions, the liability of every Member of the Council shall be unlimited; and the liability of every Member of the Association who has received any such dividend, bonus, or other profit as aforesaid, shall likewise be unlimited.

7th. Every Member of the Association undertakes to contribute to the Assets of the Association in the event of the same being wound up during the time that he is a Member, or within one

year afterwards, for payment of the debts and liabilities of the Association contracted before the time at which he ceases to be a Member, and of the costs, charges, and expenses for winding up the same, and for the adjustment of the rights of the contributories amongst themselves, such amount as may be required not exceeding Five Shillings, or in case of his liability becoming unlimited such other amount as may be required in pursuance of the last preceding paragraph of this Memorandum.

8th. If upon the winding up or dissolution of the Association there remains, after the satisfaction of all its debts and liabilities, any property whatsoever, the same shall not be paid to or distributed among the Members of the Association, but shall be given or transferred to some other Institution or Institutions having objects similar to the objects of the Association, to be determined by the Members of the Association at or before the time of dissolution; or in default thereof, by such Judge of the High Court of Justice as may have or acquire jurisdiction in the matter.

Articles of Association.

FEBRUARY 1893.

(*Article* 23 *revised March* 1902.)

INTRODUCTION.

Whereas an Association called "The Institution of Mechanical Engineers" existed from 1847 to 1878 for objects similar to the objects expressed in the Memorandum of Association of the Association (hereinafter called "the Institution") to which these Articles apply;

And whereas the Institution was formed in 1878 for furthering and extending the objects of the former Institution, by a registered Association, under the Companies Acts 1862 and 1867;

And whereas terms used in these Articles are intended to have the same respective meanings as they have when used in those Acts, and words implying the singular number are intended to include the plural number, and *vice versâ*;

NOW THEREFORE IT IS HEREBY AGREED as follows:—

CONSTITUTION.

1. For the purpose of registration the number of members of the Institution is unlimited.

MEMBERS, ASSOCIATE MEMBERS, GRADUATES, ASSOCIATES, AND HONORARY LIFE MEMBERS.

2. The present Members of the Institution, and such other persons as shall be admitted in accordance with these Articles, and none others, shall be Members of the Institution, and be entered on the register as such.

3. Any person may become a Member of the Institution who shall be qualified and elected as hereinafter mentioned, and shall agree to become such Member, and shall pay the entrance fee and first subscription accordingly.

4. The qualification of Members shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

5. The election of Members shall be conducted as prescribed by the By-laws from time to time in force, as provided by the Articles.

6. In addition to the persons already admitted as Graduates, Associates, and Honorary Life Members respectively, the Institution may admit such persons as may be qualified and elected in that behalf as Associate Members, Graduates, Associates, and Honorary Life Members respectively of the Institution, and may confer upon them such privileges as shall be prescribed by the By-laws from time to time in force, as provided by the Articles: provided that no Associate Member, Graduate, Associate, or Honorary Life Member shall be deemed to be a Member within the meaning of the Articles.

7. The qualification and mode of election of Associate Members, Graduates, Associates, and Honorary Life Members shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

8. The rights and privileges of every Member, Associate Member, Graduate, Associate, or Honorary Life Member shall be personal to himself, and shall not be transferable or transmissible by his own act or by operation of law.

ENTRANCE FEES AND SUBSCRIPTIONS.

9. The Entrance Fees and Subscriptions of Members, Associate Members, Graduates, and Associates shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

EXPULSION.

10. If any Member, Associate Member, Graduate, or Associate shall leave his subscription in arrear for two years, and shall fail to pay such arrears within three months after a written application has been sent to him by the Secretary, his name may be struck off the register by the Council at any time afterwards, and he shall thereupon cease to have any rights as a Member, Associate Member, Graduate, or Associate, but he shall nevertheless continue liable to pay the arrears of subscription due at the time of his name being so struck off: provided always that this regulation shall not be construed to compel the Council to remove any name, if they shall be satisfied the same ought to be retained.

11. The Council may refuse to continue to receive the subscriptions of any person who shall have wilfully acted in contravention of the regulations of the Institution, or who shall in the opinion of the Council have been guilty of such conduct as shall have rendered him unfit to continue to belong to the Institution; and may remove his name from the register, and he shall thereupon cease to be a Member, Associate Member, Graduate, or Associate (as the case may be) of the Institution.

GENERAL MEETINGS.

12. The General Meetings shall consist of the Ordinary Meetings, the Annual General Meeting, and of Special Meetings as hereinafter defined.

13. The Annual General Meeting shall take place in London in one of the first four months of every year. The Ordinary Meetings shall take place at such times and places as the Council shall determine.

14. A Special Meeting may be convened at any time by the Council, and shall be convened by them whenever a requisition signed by twenty Members or Associate Members of the Institution,

specifying the object of the Meeting, is left with the Secretary. If for fourteen days after the delivery of such requisition a Meeting be not convened in accordance therewith, the Requisitionists or any twenty Members or Associate Members of the Institution may convene a Special Meeting in accordance with the requisition. All Special Meetings shall be held in London.

15. Seven clear days' notice of every Meeting, specifying generally the nature of any special business to be transacted at any Meeting, shall be given to every person on the register of the Institution, except as provided by Article 35, and no other special business shall be transacted at such Meeting; but the non-receipt of such notice shall not invalidate the proceedings of such Meeting. No notice of the business to be transacted (other than such ballot lists as may be requisite in case of elections) shall be required in the absence of special business.

16. Special business shall include all business for transaction at a Special Meeting, and all business for transaction at every other Meeting, with the exception of the reading and confirmation of the Minutes of the previous Meeting, the election of Members, Associate Members, Graduates, and Associates, and the reading and discussion of communications as prescribed by the By-laws, or by any regulations of the Council made in accordance with the By-laws.

PROCEEDINGS AT GENERAL MEETINGS.

17. Twenty Members or Associate Members shall constitute a quorum for the purpose of a Meeting other than a Special Meeting. Thirty Members or Associate Members shall constitute a quorum for the purpose of a Special Meeting.

18. If within thirty minutes after the time fixed for holding the Meeting a quorum is not present, the Meeting shall be dissolved, and all matters which might, if a quorum had been present, have been done at a Meeting (other than a Special Meeting) so dissolved, may forthwith be done on behalf of the Meeting by the Council.

19. The President shall be Chairman at every Meeting, and in his absence one of the Vice-Presidents; and in the absence of all Vice-Presidents a Member of Council shall take the chair; and if no Member of Council be present and willing to take the chair, the Meeting shall elect a Chairman.

20. The decision of a General Meeting shall be ascertained by show of hands, unless, after the show of hands, a poll is forthwith demanded; and by a poll, when a poll is thus demanded. The manner of taking a show of hands or a poll shall be in the discretion of the Chairman; and an entry in the Minutes, signed by the Chairman, shall be sufficient evidence of the decision of the General Meeting. Each Member and Associate Member shall have one vote and no more. In case of equality of votes the Chairman shall have a second or casting vote: provided that this Article shall not interfere with the provisions of the By-laws as to election by ballot.

21. The acceptance or rejection of votes by the Chairman shall be conclusive for the purpose of the decision of the matter in respect of which the votes are tendered: provided that the Chairman may review his decision at the same Meeting, if any error be then pointed out to him.

BY-LAWS.

22. The By-laws set forth in the schedule to these Articles, and such altered and additional By-laws as shall be substituted or added as hereinafter mentioned, shall regulate all matters by the Articles left to be prescribed by the By-laws, and all matters which consistently with the Articles shall be made the subject of By-laws. Alterations in, and additions to, the By-laws, may be made only by resolution of the Members and Associate Members at an Annual General Meeting, after notice of the proposed alteration or addition has been announced at the previous Ordinary Meeting, and not otherwise.

COUNCIL.

23. The Council of the Institution shall be chosen from the Members only; and shall consist of one President, six Vice-Presidents, twenty-one ordinary Members of Council, and of the Past-Presidents. The President, two Vice-Presidents, and seven Members of Council (other than Past-Presidents), shall retire at each Annual General Meeting, but shall be eligible for re-election. The Vice-Presidents and Members of Council to retire each year shall, unless the Council agree otherwise among themselves, be chosen from those who have been longest in office, and in cases of equal seniority shall be determined by ballot.

24. The election of a President, Vice-Presidents, and Members of Council, to supply the place of those retiring at the Annual General Meeting, shall be conducted in such manner as shall be prescribed by the By-laws from time to time in force, as provided by the Articles.

25. The Council may supply any casual vacancy in the Council (including any casual vacancy in the office of President) which shall occur between one Annual General Meeting and another; and the President, Vice-Presidents, or Members of Council so appointed by the Council shall retire at the succeeding Annual General Meeting. Vacancies not filled up at any such Meeting shall be deemed to be casual vacancies within the meaning of this Article.

OFFICERS.

26. The Treasurer, Secretary, and other employés of the Institution shall be appointed and removed in the manner prescribed by the By-laws from time to time in force, as provided by the Articles. Subject to the express provisions of the By-laws, the officers and servants of the Institution shall be appointed and removed by the Council.

27. The powers and duties of the officers of the Institution shall, subject to any express provision in the By-laws, be determined by the Council.

POWERS AND PROCEDURE OF COUNCIL.

28. The Council may regulate their own procedure, and delegate any of their powers and discretions to any one or more of their body, and may determine their own quorum: if no other number is prescribed, three members of Council shall form a quorum.

29. The Council shall manage the property, proceedings, and affairs of the Institution, in accordance with the By-laws from time to time in force.

30. The Treasurer may, with the consent of the Council, invest in the name of the Institution any moneys not immediately required for the purposes of the Institution in or upon any of the following investments (that is to say):—

(A) The Public Funds, or Government Stocks of the United Kingdom, or of any Foreign or Colonial Government guaranteed by the Government of the United Kingdom.

(B) Real or Leasehold Securities, or in the purchase of real or leasehold properties in Great Britain or Ireland.

(C) Debentures, Debenture Stock, or Guaranteed or Preference Stock, of any Company incorporated by special Act of Parliament, the ordinary Shareholders whereof shall at the time of such investment be in actual receipt of half-yearly or yearly dividends.

(D) Stocks, Shares, Debentures, or Debenture Stock of any Railway, Canal, or other Company, the undertaking whereof is leased to any Railway Company at a fixed or fixed minimum rent.

(E) Stocks, Shares, or Debentures of any East Indian Railway or other Company, which shall receive a contribution from His Majesty's East Indian Government of a fixed annual percentage on their capital, or be guaranteed a fixed annual dividend by the same Government.

(F) The security of rates levied by any corporate body empowered to borrow money on the security of rates, where such borrowing has been duly authorised by Act of Parliament.

31. The Council may, with the authority of a resolution of the Members and Associate Members in General Meeting, borrow moneys for the purposes of the Institution on the security of the property of the Institution, or otherwise at their discretion.

32. No act done by the Council, whether *ultra vires* or not, which shall receive the express or implied sanction of the Members and Associate Members in General Meeting, shall be afterwards impeached by any member of the Institution on any ground whatsoever, but shall be deemed to be an act of the Institution.

NOTICES.

33. A notice may be served by the Council upon any Member, Associate Member, Graduate, Associate, or Honorary Life Member, either personally or by sending it through the post in a prepaid letter addressed to him at his registered place of abode.

34. Any notice, if served by post, shall be deemed to have been served at the time when the letter containing the same would be delivered in the ordinary course of the post; and in proving such service it shall be sufficient to prove that the letter containing the notice was properly addressed and put into the post office.

35. No Member, Associate Member, Graduate, Associate, or Honorary Life Member, not having a registered address within the United Kingdom, shall be entitled to any notice; and all proceedings may be had and taken without notice to such member, in the same manner as if he had had due notice.

By-laws.

(*Last Revision, February* 1894.)

MEMBERSHIP.

1. Candidates for admission as Members must be persons not under twenty-five years of age, who, having occupied during a sufficient period a responsible position in connection with the practice or science of Engineering, may be considered by the Council to be qualified for election.

2. Candidates for admission as Associate Members must be persons not under twenty-five years of age, who, being engaged in such work as is connected with the practice or science of Engineering, may be considered by the Council to be qualified for election, though not yet to occupy positions of sufficient responsibility, or otherwise not yet to be eligible, for admission as Members. They may afterwards be transferred at the discretion of the Council to the class of Members.

3. Candidates for admission as Graduates must be persons holding subordinate situations, and not under eighteen years of age. They must furnish evidence of training in the principles as well as in the practice of Engineering. Before attaining the age of twenty-six years, those elected after 1892 must apply for election as Members, Associate Members, or Associates, if they desire to remain connected with the Institution; they may not continue Graduates after attaining the age of twenty-six.

4. Candidates for admission as Associates must be persons not under twenty-five years of age, who from their scientific attainments or position in society may be considered eligible by the Council. They may afterwards be transferred at the discretion of the Council to the class of Associate Members or of Members.

5. The Council shall have the power to nominate as Honorary Life Members persons of eminent scientific acquirements, who in their opinion are eligible for that position.

6. The Members, Associate Members, Graduates, Associates, and Honorary Life Members shall have notice of and the privilege to attend all Meetings; but Members and Associate Members only shall be entitled to vote thereat.

7. The abbreviated distinctive Titles for indicating the connection with the Institution of Members, Associate Members, Graduates, Associates, or Honorary Life Members thereof, shall be the following:—for Members, M. I. Mech. E.; for Associate Members, A. M. I. Mech. E.; for Graduates, G. I. Mech. E.; for Associates, A. I. Mech. E.; for Honorary Life Members, Hon. M. I. Mech. E.

8. Subject to such regulations as the Council may from time to time prescribe, any Member, Associate Member, or Associate may upon application to the Secretary obtain a Certificate of his membership or other connection with the Institution. Every such certificate shall remain the property of, and shall on demand be returned to, the Institution.

ENTRANCE FEES AND SUBSCRIPTIONS.

9. Each Member shall pay an Annual Subscription of £3, and on election an Entrance Fee of £2.

10. Each Associate Member shall pay an Annual Subscription of £2 10*s.*, and on election an Entrance Fee of £1. If afterwards transferred by the Council to the class of Members, he shall pay on transference 10*s.* additional subscription for the current year, and £1 additional entrance fee.

11. Each Graduate shall pay an Annual Subscription of £1 10*s.*, but no Entrance Fee. Any Graduate elected prior to 1893, if transferred by the Council to the class of Associate Members, shall pay on transference £1 additional subscription for the current year, but no additional entrance fee; if transferred direct to the class of Members, he shall pay on transference £1 10*s.* additional subscription for the current year, and £1 additional entrance fee.

12. Each Associate shall pay an Annual Subscription of £2 10*s*., and on election an Entrance Fee of £1. If afterwards transferred by the Council to the class of Associate Members, he shall pay on transference no additional subscription or entrance fee. If transferred direct to the class of Members, he shall pay on transference 10*s*. additional subscription for the current year, and £1 additional entrance fee; except Associates elected prior to 1893, who shall pay no additional entrance fee on transference.

13. All subscriptions shall be payable in advance, and shall become due on the 1st day of January in each year; and the first subscription of Members, Associate Members, Graduates, and Associates, shall date from the 1st day of January in the year of their election.

14. In the case of Members, Associate Members, Graduates, or Associates, elected in the last three months of any year, the first subscription shall cover both the year of election and the succeeding year.

15. Any Member, Associate Member, or Associate, whose subscription is not in arrear, may at any time compound for his subscription for the current and all future years by the payment of Fifty Pounds, if paid in any one of the first five years of his membership. If paid subsequently, the sum of Fifty Pounds shall be reduced by One Pound per annum for every year of membership after five years. All compositions shall be deemed to be capital moneys of the Institution.

16. The Council may at their discretion reduce or remit the annual subscription, or the arrears of annual subscription, of any Member or Associate Member who shall have been a subscribing member of the Institution for twenty years, and shall have become unable to continue the annual subscription provided by these By-laws.

17. No Proceedings or Ballot Lists or Certificates shall be sent to Members, Associate Members, Graduates, or Associates, who are in

arrear with their subscriptions more than twelve months, and whose subscriptions have not been remitted by the Council as hereinbefore provided.

ELECTION OF MEMBERS, ASSOCIATE MEMBERS, GRADUATES, AND ASSOCIATES.

18. A recommendation for admission according to Form A or B in the Appendix shall be forwarded to the Secretary, and by him be laid before the next Meeting of the Council. The recommendation must be signed by not less than five Members or Associate Members if the application be for admission as a Member or Associate Member or Associate, and by three Members or Associate Members if it be for a Graduate.

19. All elections shall take place by ballot, four-fifths of the votes given being necessary for election.

20. All applications for admission shall be communicated by the Secretary to the Council for their approval previous to being inserted in the ballot list for election, and the approved ballot list shall be signed by the President and forwarded to the Members and Associate Members. The name of any Candidate approved by the Council for admission as an Associate Member or an Associate shall not be inserted in the ballot list until he has signed the Form C in the Appendix. The ballot list shall specify the name, occupation, and address of the Candidates, and also by whom proposed and seconded. The lists shall be opened only in the presence of the Council on the day of election, by a Committee to be appointed for that purpose.

21. The Elections shall take place at the General Meetings only.

22. When the proposed Candidate is elected, the Secretary shall give him notice thereof according to Form D; but his name shall not be added to the register of the Institution until he shall have paid his Entrance Fee and first Annual Subscription, and signed the Form E in the Appendix.

23. In case of non-election, no mention thereof shall be made in the Minutes, nor any notice given to the unsuccessful Candidate.

24. An Associate Member desirous of being transferred to the class of Members, or an Associate to the class of Associate Members or of Members, shall forward to the Secretary a recommendation according to Form F in the Appendix, signed by not less than five Members or Associate Members, which shall be laid before the next meeting of Council for their approval. On their approval being given, the Secretary shall notify the same to the Candidate according to Form G; but his name shall not be added to the list of Members or Associate Members until he shall have signed the Form H, and shall have paid the additional entrance fee (if any), and the additional subscription (if any) for the current year.

ELECTION OF PRESIDENT, VICE-PRESIDENTS, AND MEMBERS OF COUNCIL.

25. Candidates shall be put in nomination at the General Meeting preceding the Annual General Meeting, when the Council are to present a list of their retiring Members who offer themselves for re-election; any Member or Associate Member shall then be entitled to add to the list of Candidates. The ballot list of the proposed names shall be forwarded to the Members and Associate Members. The ballot lists shall be opened only in the presence of the Council on the day of election, by a Committee to be appointed for that purpose.

APPOINTMENT AND DUTIES OF OFFICERS.

26. The Treasurer shall be a Banker, and shall hold the uninvested funds of the Institution, except the moneys in the hands of the Secretary for current expenses. He shall be appointed by the Members and Associate Members at a General or Special Meeting, and shall hold office at the pleasure of the Council.

27. The Secretary of the Institution shall be appointed, as and when a vacancy occurs, by the Members and Associate Members at a General or Special Meeting, and shall be removable by the Council upon six months' notice from any day. The Secretary shall give the same notice. The Secretary shall devote the whole of his time to the work of the Institution, and shall not engage in any other business or profession.

28. It shall be the duty of the Secretary, under the direction of the Council, to conduct the correspondence of the Institution; to attend all meetings of the Institution, and of the Council, and of Committees; to take minutes of the proceedings of such meetings; to read the minutes of the preceding meetings, and all communications that he may be ordered to read; to superintend the publication of such papers as the Council may direct; to have the charge of the library; to direct the collection of the subscriptions, and the preparation of the account of expenditure of the funds; and to present all accounts to the Council for inspection and approval. He shall also engage (subject to the approval of the Council) and be responsible for all persons employed under him, and set them their portions of work and duties. He shall conduct the ordinary business of the Institution, in accordance with the Articles and By-laws and the directions of the President and Council; and shall refer to the President in any matters of difficulty or importance, requiring immediate decision.

MISCELLANEOUS.

29. All Papers shall be submitted to the Council for approval, and after their approval shall be read by the Secretary at the General Meetings, or by the Author with the consent of the Council; or, if so directed by the Council, shall be printed in the Proceedings without having been read at a General Meeting.

30. All books, drawings, communications, &c., shall be accessible to the members of the Institution at all reasonable times.

31. All communications to the Meetings shall be the property of the Institution, and be published only by the authority of the Council.

32. None of the property of the Institution—books, drawings, &c.—shall be taken out of the premises of the Institution without the consent of the Council.

33. All donations to the Institution shall be enumerated in the Annual Report of the Council presented to the Annual General Meeting.

34. The General Meetings shall be conducted as far as practicable in the following order:—

1st. The Chair to be taken at such hour as the Council may direct from time to time.

2nd. The Minutes of the previous Meeting to be read by the Secretary, and, after being approved as correct, to be signed by the Chairman.

3rd. The Ballot Lists, previously opened by the Council, to be presented to the Meeting, and the new Members, Associate Members, Graduates, and Associates elected to be announced.

4th. Papers approved by the Council to be read by the Secretary, or by the Author with the consent of the Council.

35. Each Member or Associate Member shall have the privilege of introducing one friend to any of the Meetings; but, during such portion of any meeting as may be devoted to any business connected with the management of the Institution, visitors shall be requested by the Chairman to withdraw, if any Member or Associate Member asks that this shall be done.

36. Every Member, Associate Member, Graduate, Associate, or Visitor, shall write his name and residence in a book to be kept for the purpose, on entering each Meeting.

37. The President shall ex officio be member of all Committees of Council.

38. Seven clear days' notice at least shall be given of every meeting of the Council. Such notice shall specify generally the business to be transacted by the meeting. No business involving the expenditure of the funds of the Institution (except by way of payment of current salaries and accounts) shall be transacted at any Council meeting unless specified in the notice convening the meeting.

39. The Council shall present the yearly accounts to the Annual General Meeting, after being audited by a professional accountant, who shall be appointed annually by the Members and Associate Members at a General or a Special Meeting, at a remuneration to be then fixed by the Members and Associate Members.

40. Any member wishing to have a copy of the Papers sent to him for consideration beforehand can do so by sending in his name once in each year to the Secretary; and a copy of all Papers shall then be forwarded to him as early as possible prior to the date of the Meeting at which they are intended to be read.

41. At any Meeting of the Institution any member shall be at liberty to re-open the discussion upon any Paper which has been read or discussed at the preceding Meeting; provided that he signifies his intention to the Secretary at least one month previously to the Meeting, and that the Council decide to include it in the notice of the Meeting as part of the business to be transacted.

APPENDIX.

FORM A.

Mr. being years of age, and desirous of admission into The Institution of Mechanical Engineers, we, the undersigned proposer and seconder from our personal knowledge, and the three other signers from trustworthy information, propose and recommend him as a proper person to belong to the Institution.

Witness our hands, this day of

Members or Associate Members.

FORM B.

Mr. born on being desirous of admission into The Institution of Mechanical Engineers, we, the undersigned proposer and seconder from our personal knowledge, and the other signer or signers from trustworthy information, propose and recommend him as a proper person to become a Graduate thereof.

Witness our hands, this day of

Members or Associate Members.

FORM C.

If elected an of The Institution of Mechanical Engineers, I, the undersigned, do hereby engage to ratify my election by signing the form of agreement (E) and paying the Entrance Fee and Annual Subscription in conformity with the By-laws.

Witness my hand, this day of

FORM D.

Sir,—I have to inform you that on the you were elected a of The Institution of Mechanical Engineers. For the ratification of your election in conformity with the rules, it is requisite that the enclosed form be returned to me with your signature, and that your Entrance Fee and first Annual Subscription be paid, the amounts of which are and respectively. If these be not received within two months from the present date, the election will become void.

I am, Sir, Your obedient servant,

Secretary.

FORM E.

I, the undersigned, being elected a of The Institution of Mechanical Engineers, do hereby agree that I will be governed by the regulations of the said Institution, as they are now formed or as they may hereafter be altered; that I will advance the objects of the Institution as far as shall be in my power, and will attend the Meetings thereof as often as I conveniently can: provided that, whenever I shall signify in writing to the Secretary that I am desirous of withdrawing from the Institution, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand, this day of

FORM F.

Mr. being years of age, and desirous of being transferred into the class of of The Institution of Mechanical Engineers, we, the undersigned, from our personal knowledge recommend him as a proper person to be so transferred by the Council.

Witness our hands, this day of

Members or Associate Members.

FORM G.

Sir,—I have to inform you that the Council have approved of your being transferred to the class of of The Institution of Mechanical Engineers. For the ratification of your transference in conformity with the rules, it is requisite that the enclosed form be returned to me with your signature, and that your additional Entrance Fee and additional Annual Subscription for the current year be paid, the amounts of which are and respectively. If these be not received within two months from the present date, the transference will become void.

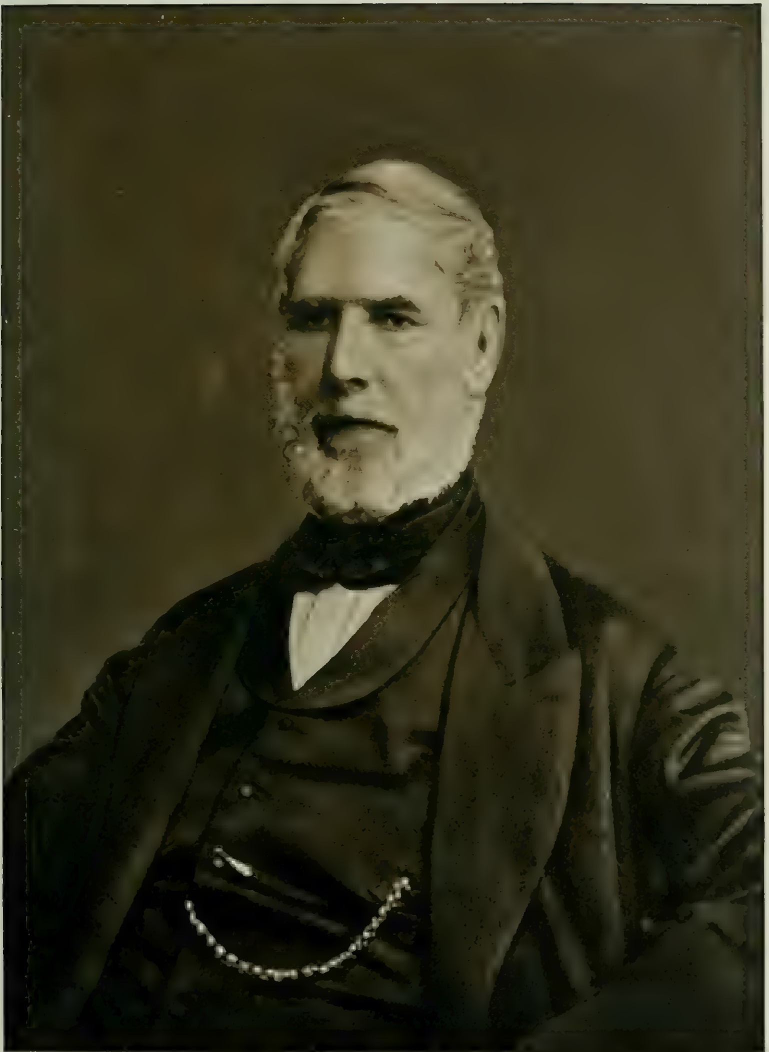
I am, Sir, Your obedient servant,

Secretary.

FORM H.

I, the undersigned, having been transferred to the class of of The Institution of Mechanical Engineers, do hereby agree that I will be governed by the regulations of the said Institution, as they now exist, or as they may hereafter be altered; that I will advance the objects of the Institution as far as shall be in my power, and will attend the Meetings thereof as often as I conveniently can: provided that, whenever I shall signify in writing to the Secretary that I am desirous of withdrawing from the Institution, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand, this day of



James Kennedy

PRESIDENT, 1860.

(Deceased 1886.)

The Institution of Mechanical Engineers.

PROCEEDINGS.

January 1905.

An Ordinary General Meeting was held at the Institution on Friday, 20th January 1905, at Eight o'clock p.m.; J. Hartley Wicksteed, Esq., President, in the chair.

The Minutes of the previous Meeting were read and confirmed.

The President announced that, in accordance with the Rules of the Institution, the President, two Vice-Presidents, and seven Members of Council, would retire at the ensuing Annual General Meeting; and the list of those retiring was as follows:—

PRESIDENT.

J. Hartley Wicksteed, ... Leeds.

VICE-PRESIDENTS.

Arthur Keen, ... Birmingham.
Edward P. Martin, ... Abergavenny.

MEMBERS OF COUNCIL.

Henry Davey, ... London.
William Dean, ... Folkestone.
H. Graham Harris, ... London.
Sir William T. Lewis, Bart., ... Aberdare.
The Right Hon. William J. Pirrie, LL.D., . . . Belfast.
Sir Thomas Richardson, ... Hartlepool.
Mark Robinson, ... Rugby.

Of these, the following had offered themselves for re-election, and had been nominated by the Council:—

VICE-PRESIDENT.

ARTHUR KEEN, ... Birmingham.

MEMBERS OF COUNCIL.

HENRY DAVEY, ... London.
WILLIAM DEAN, ... Folkestone.
H. GRAHAM HARRIS, ... London.
The Right Hon. WILLIAM J. PIRRIE, LL.D., . . Belfast.
Sir THOMAS RICHARDSON, ... Hartlepool.
MARK ROBINSON, ... Rugby.

The following Nominations had also been made by the Council for the election at the Annual General Meeting:—

PRESIDENT.

EDWARD P. MARTIN, ... Abergavenny.

VICE-PRESIDENT.

Sir WILLIAM T. LEWIS, Bart., ... Aberdare.

Election as Members. MEMBERS OF COUNCIL.

1894. GEORGE J. CHURCHWARD, ... Swindon.
1898. HAY F. DONALDSON, ... Woolwich.
1887. J. ROSSITER HOYLE, ... Sheffield.
1888. JAMES ROWAN, ... Glasgow.

All of the above had consented to the Nomination.

The PRESIDENT reminded the Meeting that, according to the Rules of the Institution, any Member or Associate Member was then entitled to add to the list of candidates.

No other names being added, the President announced that the foregoing names would accordingly constitute the nomination list for the Election of Officers at the Annual General Meeting.

The PRESIDENT announced that the Ballot Lists for the election of New Members had been opened by a Committee of the Council, and that the following fifty-four candidates were found to be duly elected :—

MEMBERS.

ANSTEY, HENRY CHARLES, Eng.-Lieut. R.N.,	Grantham.
BLAKEY, ROBERT COPE, ...	Vienna.
LAWRENCE, MAXIMILIAN ROBERT, . .	Crayford.
MONEY-KENT, JULIAN MONEY VERNON, .	London.
RICHARDSON, CHARLES ERNEST, . .	Wellington, N.Z.

ASSOCIATE MEMBERS.

ALLEN, THOMAS FEARNLEY, . . .	Buenos Aires.
ATKINSON, CYRIL JOSEPH, . . .	Manchester.
BENNETT, ALFRED TEMPLE, . . .	London.
BOULTON, CHARLES VALENTINE, . .	London.
CLACHER, THOMAS, ...	London.
COOKSLEY, ALFRED, ...	London.
COWLRICK, FRANCIS GERMAN, . . .	London.
DELL, FRANCIS ALBERT BLECKLY, . .	Croydon.
ENGLISH, ROBERT, ...	Christchurch, N.Z.
FLETCHER, FRANK PURSER, . . .	Woolwich.
GRAY, JAMES, ...	Bristol.
GREEN, FREDERICK WALTON, . . .	Wolverhampton.
HAMBLIN, HENRY JOEL, ...	Bath.
HARRISON, RICHARD, ...	Hull.
HOLLIDAY, CHARLES EDWARD, . . .	Manchester.
HOLROYDE, GEORGE ERNEST, . . .	Brisbane.
HUDLASS, FELIX WILLIAM ISHERWOOD, .	London.
HUNTER, JOHN WILLIAM, . . .	London.
INCE, ROBERT SELF, ...	London.
MALCOLM, GEORGE WILLIAM, . . .	Mauritius.
MAY, HORACE NUNN, ...	Rugby.
PORTER, RALPH CLASSON, . . .	Birmingham.
REID, JOHN ALEXANDER, . . .	London.
ROBERTSON, WILLIAM DUNLOP, . .	Dublin.

ROBINSON, ISAAC VINCENT, . . .	Glasgow.
SEYMOUR, JOHN HENRY, ...	Newport, I.W.
SHORTHOUSE, BENJAMIN, ...	London.
SPICER, FREDERICK LEMUEL, . . .	Rugby.
STOTESBURY, RICHARD HENRY, . . .	Stonehouse, Glos.
SUTTON, MARK, ...	Rio de Janeiro.
TALBOT, ERNEST, ...	Mansfield.
TAYLOR, CHARLES ALBERT, . . .	London.
TAYLOR, WILFRID, ...	Hull.
TOMS, ROBERT, ...	Exeter.
TURNER, EUSTACE HOOPER, . . .	London.
VICKERS, ERNEST JOHN, ...	London.
WOOD, HARRY HERBERT ELLIOTT, . .	London.

GRADUATES.

ARMSTRONG, ANDREW ROBERT BARRY, .	Dublin.
CHURCH, HERBERT JOHN, . . .	Bristol.
EDWARDS, CECIL CLEEVE, . . .	Port Elizabeth.
HILLHOUSE, JOHN PATON, . . .	Birmingham.
JOPLING, ARTHUR, ...	Blaydon-on-Tyne.
MANFIELD, WALTER GUY, . . .	Weymouth.
McDONALD, NEIL, ...	Cardiff.
NORRISH, HUGH ROPER BARRETT, . .	London.
STERN, SYDNEY LEONARD, . . .	London.
TUNBRIDGE, EDWARD WILLIAM, . .	Birmingham.
WILMAN, EDGAR ARTHUR, . . .	Bradford.
YATES, REGINALD CHOLMELEY CAMPBELL, .	Manchester.

The PRESIDENT announced that the following three Transferences had been made by the Council since the last Meeting:—

Associate Members to Members.

ATHERTON, WILLIAM HENRY, ...	London.
CARNEGIE, WILLIAM, ...	Woolwich.
SIRRI, Lieut-Commander M., ...	Constantinople.

The four following Papers were read and partly discussed jointly:—

"Some Impressions of American Workshops"; by Mr. A. J. GIMSON, *Member*, of Leicester.

"Waterworks Pumping Engines in the United States and Canada"; by Mr. JOHN BARR, *Associate*, of Kilmarnock.

"Some features in the Design and Construction of American Planing Machines"; by Mr. ARCHIBALD KENRICK, JUN., *Associate Member*, of Tunbridge Wells.

"Engines at the Power-Stations, and at the St. Louis Exhibition"; by Mr. ALFRED SAXON, *Member*, of Manchester.

The Meeting terminated at a Quarter to Ten o'clock. The attendance was 208 Members and 79 Visitors.

SOME IMPRESSIONS OF AMERICAN WORKSHOPS.

BY MR. A. J. GIMSON, *Member*, OF LEICESTER.

When in America the author visited sixteen Engineering Workshops situated in cities far distant from one another, and comprising works for the manufacture of steam-engines, pumping machinery, shafting and pulleys, machine tools, elevators, and valves. Any ideas that may be here set down are of a very general character, for it was not the author's intention to inspect or investigate any special class of work. The works visited ranged from factories at least two generations old, where generally a considerable variety of work was undertaken, to modern workshops of only a few years' growth, where a special class of machine was alone manufactured. The very best of these workshops, with possibly one exception, could be matched in equipment and in general methods of carrying out work by single works in this country. Some of them were in no way in advance of ordinary practice here. In general, however, the organization of an engineer's workshop in America struck the author as superior to that in similar works in England, whilst in some the organization was in every detail admirably thought out and administered. In a modern business an American begins to make one particular machine or particular kind of machine. His whole energy is, in the first instance, concentrated upon making this

machine superior to anything at the time upon the market. More than with us, he thinks that natural ability is aided by the best scientific knowledge in the design of the machine to be produced.

A feature of the engineering industry that impressed the author was the close intercommunication of Technical Institutes and manufacturing workshops, of professors and manufacturers, and the presence, in minor positions of authority, of young men who had passed through a complete course of technical instruction. The American employer gives one the impression of being a firm believer in the merit of the machine he is manufacturing. Doubt is eliminated from his mind, and he can enter whole-heartedly into the processes of manufacturing his particular article without a fear that it may not meet the needs of his customer. His confidence is based on a very complete knowledge of his subject, and not upon an over-exalted belief in his own special ability. When the actual making of the machine designed comes to be undertaken, it is essential that accuracy and economy of production shall be attained. Methods were observed for obtaining accurate machine work, and methods of testing the accuracy of machines as they were being put together, which were admirable in their approach towards perfection. No detail is too trivial to be well thought out, and the tests are such that their object is attained without needing any considerable expenditure of time on the part of the workman. Although he did not remember having seen any workmen exerting themselves more than is usual in shops here, the author is convinced that more work is obtained from them by the close study of economies by the staff in the drawing and allied offices.

An American employer will see that his workmen have no reason to use their time for any purpose in which they are not skilled. His foremen will do no clerk's work. His machine men will not be grinders of tools nor designers and constructors of methods for holding and machining the work. A machine minder's business is to keep his machine moving and his tools cutting every minute of the day that is possible. It is relegated to others to design, to grind, to fetch and carry his tools, to prepare chucks, jigs and everything requisite, so that they may be ready to the workman's hand at the

time they are wanted; and to his foreman is relegated the chief duty of seeing that the work is quickly and correctly done. It would be instructive to some here to know what proportion of the time of a factory's running is used by any given machine in actually performing the work it is designed to do. The author has seen a Works where every separate job for every machine is ordered and arranged from the office staff, where every detail in the process of its machining is settled, and the number of minutes each process must occupy is displayed before the article reaches the workman's hands. In such a Works a liberal bonus is paid for a saving in time, and rigorous methods are in force against those who fail to carry out the work in the stipulated time. Such methods may appear harsh, but he believes that in practice they are not so, for they are the result of accurate experience gained by an expert staff, and they recognize the enormous difference, in industry and ability, that there is between different workmen. The able man is allowed full play for his ability, and is rewarded by a very great increase in money earned over his slower or less industrious neighbour. In the same way, by card index processes, by clocks with dials divided into tenths and hundredths, are minutes saved which a workman uses in calculating his time, and which a clerk wastes in complicated addition and multiplication of figures. Persistent energy and patience have achieved remarkable results in the organization of cheap production in some of these workshops. This, the author thinks, is the chief difference, stated in general terms, between English and American workshop practice. In this country they are somewhat wasteful of the workmen's time; in America they are careful of it to a remarkable extent. It follows that if American engineers shall compete successfully against English engineers, it will be, in his opinion, because the organizers of their businesses know their work, and carry it out better than do the organizers of businesses here. Their workmen are in no way superior, but their skill and ability are used to better advantage.

In matters of design, as distinct entirely from methods of manufacture, the author did not note great differences between American and English practice. On both sides of the Atlantic the same problems are attacked on similar lines: in details they differ, but not

in principles. It would seem that there is much to be learnt from each other in these things, and that the more friendly rivalry there is between the engineers of the two nations, the better will it be for the engineering industry of the world. The author believes that no one who visited America with this Institution can fail to have been impressed with the cordiality with which they were received, and the exceeding trouble which was taken to make their visit interesting, instructive, and pleasant; and he entertains a grateful remembrance of their hospitality.

Discussion on 20th January 1905.

The PRESIDENT asked the members to convey by acclamation their thanks for Mr. Gimson's Paper. He thought the description of the best American workshops which the author had given would serve as a description of Mr. Mark Robinson's workshops at Rugby, and he would invite that gentleman to open the discussion.

The thanks of the Institution were accorded to the author by acclamation.

Mr. MARK ROBINSON, Member of Council, thought the Paper was an interesting and instructive one, and that all members might benefit by reading it in full. He believed the author went to the root of the subject in saying that the superiority of American workshops and American methods, real as he believed it to be in many cases (though even in those perhaps less pronounced than some supposed), was almost entirely due to better organization rather than to better tools or better men. He thought the reference to the steps taken to prevent waste of time, as by not allowing foremen to do clerks' work, or skilled men to do work which unskilled men might do, was very useful and instructive.

Mr. W. Stanley Bott said he would like to make a few remarks on this Paper. The author said (page 9): "It follows that if American engineers shall compete successfully against English engineers, it will be, in his opinion, because the organizers of their businesses know their work, and carry it out better than do the organizers of businesses here." Then he went on to say: "Their workmen are in no way superior, but their skill and ability are used to better advantage." On page 8 he said: "The author is convinced that more work is obtained from them by the close study of economies by the staff in the drawing and allied offices." On page 7 he said: "In general, however, the organization of an engineer's shop in America struck the author as superior to that in similar works in England." He thought from those remarks that Mr. Gimson's real opinion was that Americans were competing successfully against the English. His own impression of the twelve or fourteen shops he saw was that the majority of them were better laid out and better organized than many of the shops in England. A few of the shops in England were quite equal to any in America, but he thought a great many were still behindhand. The American superiority, as Mr. Robinson had said, was the result of better organization. They looked after every little detail; they kept more accurate time records, and went much more minutely into the amount of time spent on a job than was done in England. They certainly had a better system of cost-keeping. He did not think English engineers went minutely enough into cost-keeping systems. Such systems had resulted from the fact that Americans specialised in one thing and were thus able to carry out the work more thoroughly. In shops in England, where more than one class of machine was made, it was practically impossible to specialise and to keep costs so minutely as where one did specialise.

At the top of page 9 Mr. Gimson said: "It would be instructive to some here to know what proportion of the time of a factory's running is used by any given machine." He did not know quite to whom the "some" applied; it seemed to him that nobody in England could run his business very well unless he did have

(Mr. W. Stanley Bott.)
such information. Mr. Gimson also referred to card index processes (page 9). Probably a good many members knew what the card index was, but to those who did not know he would say: "Go and learn it and get enthusiastic over it." He became acquainted with a card index about four and a half years ago, and got very enthusiastic over it. He was quite sure that in any engineering works it would be found that great benefit would be derived from its use. But it was necessary to be enthusiastic about it, because if it were not used properly, it was worse than useless.

Mr. Charles Wicksteed said that he went over to America to learn all that he could of American methods, and to see if what people said about them was true, rather than to examine any particular machine, although there was an immense amount of beautiful machinery that it would have been well worth his while to have examined thoroughly, if he could have found time to do so. People said to him in America: "Is not this beautiful machinery?" He replied: "Yes, but we have it all in England; owing to our free trade we have been able to get the best of your machinery." He saw nothing particularly new in America, not because they had not brought out a number of beautiful things, but because England bought all the good American machinery, and had its own good machinery as well. He liked to stand up for the "Old Country" a little bit, and he therefore, whether right or wrong, told Americans that English engineering shops for general purposes were better equipped than their shops were, because English shops had the pick of the two countries, whereas Americans with their high protection only had their own machinery.

He had always heard that Americans worked a good deal harder than people in this country. He did not wish to set himself up as an authority; he was simply stating what his honest convictions were. He looked everywhere, in the workshops and in the streets; he observed the men in the booking offices at the railway stations, at the post office, and everywhere else, and as far as he could judge he came to the conclusion that they were not working any harder than Englishmen. In all matters of personal service, such as in the post

office, telegraph office, porterage or anything of that kind, English were far away the smarter and more efficient. But Americans worked hard in one way, namely, that they never seemed to leave off. The hours were extremely long, and night and day work seemed to be very usual.

English people talked about the wonderful American workshops, and he was told before he went over there that he would find them much better than ours. He came to the conclusion, however, that those who thought the American workshops so decidedly superior to British were people who had never seen the best workshops in this country; they had only seen second- and third-class places in England, and had then gone to America and seen the very best that America had to show them, and returning home, imagined that England was backward. Of course England suffered certain disadvantages as well as advantages in being an old country. In this country the most antiquated machinery, or no machinery at all, would be found in the oldest centres of industry—in Birmingham, and Leeds, and so on. In those great old towns it was a wonder that some of the shops could exist at all. The finest workshops were often found in such places as Rugby, which had not long been known to the mechanical world. There were innumerable works in England equal to anything he saw in America. He would point out that in America, with its rapidly developing industries and endless resources, there was a greater proportion of new workshops than in England, and that the scarcity and dearness of skilled labour made method, duplicate production, and automatic machinery essential for their industrial existence. They therefore naturally applied themselves to such organization, and had done it well. The Americans were exceedingly proud of all their splendidly equipped works—in fact they were proud of everything. Even if it was a bad thing, they were proud of it, as long as there was enough of it. At the same time, he thought that in American shops there was often waste, and that Americans were sometimes too lavish in the size and equipment of their works. A number of the great show places were paying very little dividend, and some of them none at all. He maintained, as an ordinary engineer, that one had every reason to be proud of a

(Mr. Charles Wicksteed.)

beautiful shop, spacious buildings, wonderful machinery, and a magnificent floor space, provided the concern paid; but if it did not pay, and if the company had to be reconstructed, and so on, he thought there was something to be ashamed of instead of something to brag about. The members must not imagine that he was trying to run down America. He had no doubt he would very soon be talking "big" if he were an American. The fact of the matter was that the Americans were great at big things; there was no mistake about that. When he was in America he was told that Americans were the smartest people on the face of the earth, and that Englishmen were exceedingly old-fashioned slow-coaches, who did not move at all; but he confessed the conclusion he came to was that American progress was brilliant in certain particulars, was more irregular than English, and had ghastly and dangerous chasms between the pinnacles of success, whilst English progress was, on the whole, more satisfactory and even. He often felt quite ashamed of the muddling shops which were spread all over this country, and the squatty sheds in which business was carried on, compared with the good shops which he saw in America, and which he supposed largely prevailed over that country. But, on the whole, he came away with the idea that if England would only accept all she could take from America, and other countries, as a small return for the immensely greater amount that she herself had contributed to the world's engineering knowledge, she would have nothing to fear from American, or any other, competition.

There was no doubt that there was too little method over here. English engineers began without any method at all, and then adopted it very grudgingly, as a necessity; but the Americans loved it, and the infinite pains they took in elaborating the most complete system filled all with admiration. He confessed, however, that sometimes there appeared to be too much of it. They elaborated highly complicated and wonderful structures when simpler ones, such as are in vogue here, would do much better—railway tickets for instance. Their systems often broke down too, and a complex system not carried out was the worst system possible. Neither must it be thought,

although they had more and better systems in their engineering works, that this was universally the case outside; it was quite the contrary. He could tell stories of railway management which would stagger Englishmen, and of many instances where our methods were far simpler and more efficient than those which prevailed in America.

In conclusion, he would point out that, although, nationally speaking, England was as conceited as any nation on the face of the earth, and without doubt thought its people the chosen race, and that their worst was better than other people's best, yet nevertheless, industrially, he thought it had been the fashion lately for Englishmen to depreciate themselves, and they had been advertising their depreciation. He was bound to confess that he thought their friends in America appreciated themselves now; if Americans appreciated themselves 50 per cent., and Englishmen depreciated themselves 25 per cent., it would account for an immense amount of American superiority not to be accounted for in any other way.

Discussion on 17th February 1905.

Mr. DANIEL ADAMSON said that Mr. Gimson in his Paper had remarked that the "whole energy of the manufacturer in the first instance was concentrated on making his machine superior to anything at the time on the market." He himself thought that manufacturers in this country would only be too happy if there were the same conditions here, but unfortunately English energies were diverted in other directions. One very troublesome matter was finding customers who were prepared to look farther into the matter than the price, and he thought most manufacturers would sympathise with him in that remark. He desired to offer an explanation of the different commercial conditions in the two countries. In America first-class railway securities, over the last 10 or 12 years for comparison, returned about 33 per cent. more on the capital outlay than was returned in England. Now, if so much better

(Mr. Daniel Adamson.)

return was obtained from investments by simply buying the shares and sitting down and drawing the dividends, it would be readily understood that the possible profits from ordinary trade and business must be very much higher in America than in this country. That great advantage from a commercial point of view allowed experiments to be tried over there which people in this country would be afraid of undertaking. If a mistake was made here, it meant a serious loss which could not be recouped, except over a very long period. This state of affairs in America created a more optimistic atmosphere amongst purchasers, and makers as well; it encouraged the makers to make greater efforts to please their customers, and the customer was not afraid of buying something which in this country might be considered experimental.

Mr. Gimson also alluded to better intercourse between the manufacturing workshops and the schools and professors. One often heard of better use being made of University graduates and such educated men in business in America than was the case here. It might be that they were better prepared for the duties of business life than they were in this country. Certainly the school graduates found occupations in America much more readily than they did here. But was it not a fact that the English-shop trained men were also considered very acceptable in America even amongst their better trained college men? He (Mr. Adamson) believed that the explanation of all this lay in the more profit obtainable from business that he had just alluded to.

Mr. Gimson had referred to the "rigorous methods that were in force against those who failed to carry out work in the stipulated time." Papers had been read and favourably criticised at this Institution on a system of paying labour by results—the premium system. It might not have been noticed, however, that recently some of the most powerful Trades Unions in this country in conference had condemned that system, so that to a certain extent the English manufacturers' hands were at present tied in a great many trades. The Trades Unions said that the system "deprived the workman of the full value of his labour," and they recommended their members to have nothing to do with it, "as it was disastrous

to sound and honest workmanship"—that was the gist of the report of these Trade Unionists. He mentioned that as another example of the difficulties manufacturers had to contend with in this country. If English manufacturers used "rigorous methods against those who failed to carry out work in a stipulated time," the newspapers would have plenty of matter with which to fill their columns for some time. But, in spite of those difficulties, he thought the members would agree that English manufacturers did very well. Take, for example, the pumping engines and planing machines that had been referred to in the Papers under discussion. He was surprised that none of the authors had referred to the one thing that had made his mouth water in America, namely, the magnificent erecting shops of the West Allis Works. He asked the members to imagine a shop about 600 feet long, 120 feet wide, and 75 feet high under the cranes; with such a shop and machine-tools to match, building engines such as were referred to in Mr. Saxon's Paper was mere child's play. Comparing those engines with the larger marine engines built in the North of England and in Scotland, he thought the latter showed the more credit to the engineers who had built them in shops not nearly so well equipped as the West Allis shops. The people who ought to go to America, he contended, were customers and especially those members of the Institution who were consulting engineers, and others who advised customers in engineering matters. If they would go to America and other countries more frequently and see the methods adopted, and the methods accepted, and the methods which answered the purpose in America, he thought they would return to this country and with greater confidence spend their money or their clients' money amongst British engineers. As Mr. Simpson had remarked (page 49), with regard to the pumping engines, if customers were prepared to order larger engines they would find the British engineers quite prepared, and only too glad to build them.

There were two points of detail in connection with the Joint Meeting that had not been referred to; one was something which might be favourably considered and the other something to avoid—something which was not done in this country now, and he supposed never would be done. The American Society evidently allowed a

(Mr. Daniel Adamson.)

great number of friends to join them at their meetings; the English Institution also allowed visitors, but excluded them from visits to works and certain special privileges. Apparently, in America, the guest was allowed all the privileges of membership, with the result, he suggested, that it taxed the hospitality of their hosts, and, to that extent, interfered with the advantages that true members had in joining the Institution. There must have been at least as many guests as members on the visits to the works. The guests wore a distinguishing badge, so that it was easy to judge of their numbers. A point that was worth the consideration of the Institution at the Summer Meetings was the American plan of labelling each member, who was given a numbered badge, with his name upon it. Many members must have experienced at the Summer Meetings a difficulty in remembering the names of persons whose faces were perfectly familiar to them. There were also men whom one had heard of and would like to know, and if their names were seen one could at once become acquainted with them. It seemed to him that this system was well worth a trial.

Communications.

Mr. WILLIAM SCHÖNHEYDER wrote that he was pleased to see that attention had been called to the fact (page 7) that "In general, the organization of an engineer's workshop in America struck the author as superior to that in similar works in England." The writer's experience in this direction might not be as extensive as Mr. Gimson's, but still it was fairly large, and, as far as it went, it entirely accorded with what had been expressed. The great difficulty—the almost impossibility—of modifying and improving the work once given up to hand-work and old-fashioned and conservative methods, could hardly be over-estimated. How, excepting by organization and

labour-saving tools, was it possible for the States to undersell us in this country so largely, even in spite of their higher wages bill? He admired very much the outspoken manner adopted in this Paper.

Mr. GIMSON wrote that he was obliged for the interest shown in the subject of his Paper by the speakers, and to find all who went to America in general agreement as to the difference in American and English practice. Mr. Charles Wicksteed truly said that they had in this country their own good machinery and also the advantage of taking the best American machinery into their shops. The same might be said of the ideas of both countries. Ideas were more free than commodities. They had the opportunity of learning many things from their American friends, who might, none the less, learn some things from the British. Engineering was a progressive business. There was no fear but that for many years useful and profitable work could be found for all on both sides of the water, who did not allow their minds to stagnate. There was great value in the technical graduate element in the American shops, but no technical knowledge could supersede the necessity for workshop experience. It was no doubt this reason that enabled so many British shop-trained mechanics to obtain positions of responsibility in American shops. The specializing of work would tend to diminish the extent of a man's responsibility whilst enabling him within a limited range to reach a higher degree of ability. In this country they were more accustomed to an all-round responsibility for the completed works undertaken in our shops. Specialization was necessary for the sake of economy and accuracy combined. There would remain a place, perhaps the most important of all, for the man of engineering instinct and business ability who could utilize to the best advantage the various specialists whom a technical training would in the future provide, both here and in America.

WATERWORKS PUMPING ENGINES IN THE UNITED STATES AND CANADA.

BY MR. JOHN BARR, *Associate*, OF KILMARNOCK.

On the occasion of the recent Summer Meeting of this Institution in America, the author of this Paper availed himself of the many courtesies extended to the Members by their hosts. He has therefore set down a few notes of his observations of typical waterworks in America; these impressions have been summarised, and they are followed by brief descriptions of the pumping-engines in twelve stations, for particulars of which the author is indebted to the various engineers in charge and others to whom he wishes here to express his acknowledgments. The pumping stations described are as follows:—Schenectady, Cincinnati, Philadelphia, Pittsburg (2), Chicago, St. Louis, Desmoines, Minneapolis, Winnipeg, Toronto, London (Ontario), and Boston.

The following are the deductions referred to above:—

1. The type of high-duty waterworks pumping-engine in the United States is generally that of rotatory vertical triple-expansion; this is undoubtedly the most modern type, gives best duty, and seems to be the favourite.

2. The steam-valves are Corliss in the high-pressure cylinder, usually Corliss in the intermediate cylinders, and poppet in the low-pressure cylinder.

3. Piston speed is usually about 200 feet per minute, sometimes a little higher.

4. Duty under test-run varies from 140 to 160 millions of foot-lbs. per 1,000 lbs. of steam, for engines having a daily capacity of from 10 to 15 millions of gallons pumped into mains against a pressure of about 100 lbs. per square inch.

5. Pumps work quite well and quietly with suction under a head of pressure, air-vessels of ample capacity and means for keeping them charged with air being provided.

6. Air-vessels of ample size are provided both on suction and delivery pipes. It is a common practice to have an air-vessel on top of each delivery-valve, the three air-vessels being equalised by a connecting-pipe.

7. Pump-valves are of the multiple type of rubber or vulcanite backed by a brass or phosphor-bronze spring. Valves are about 4 inches diameter, and are very frequently set in cages placed in a strong plate in valve casing.

8. Centre crank-pin of large pumping-engines has one end in square block carefully fitted into a slot in the web of the crank on one side to allow "accommodation."

9. Journals are almost invariably lined with "Babbett" metal.

10. A heater is frequently inserted in exhaust-pipe between the low-pressure cylinder and condensers. The rise in temperature thus gained by feed-water cannot be great, but is considered worth getting.

11. Many of these large engines are splendid examples of mechanical engineering, being smooth working, efficient and well-finished machines.

Schenectady Water Works.

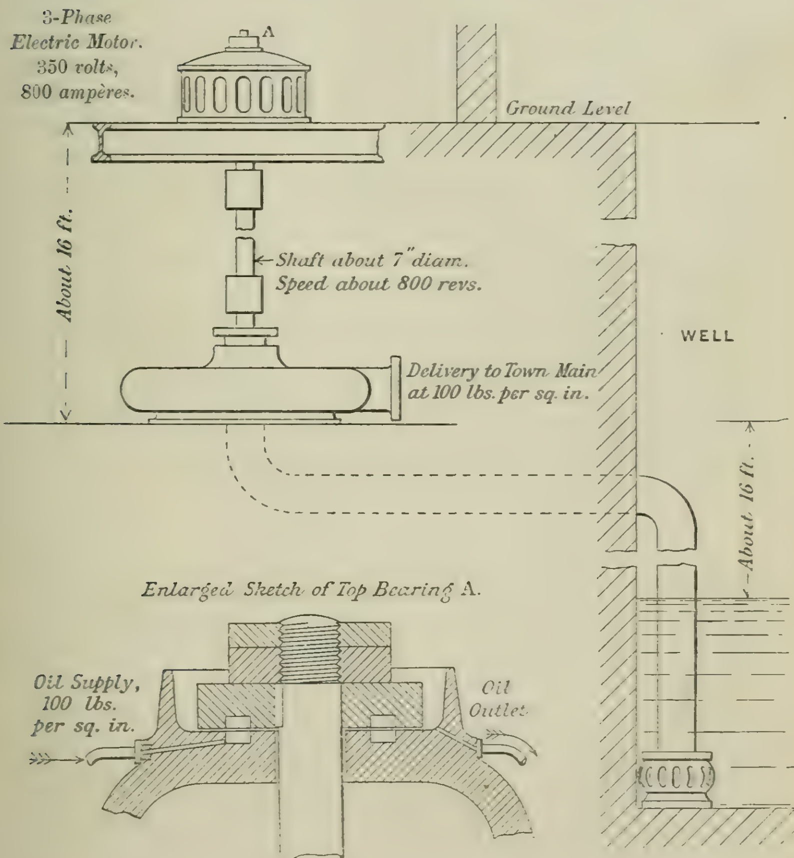
At these works are two triple-expansion vertical condensing "Deane" pumps, duplex, which pump about 20 million gallons per 24 hours, and seem to do good work. The new pumping plant recently put down consists of an electric motor running horizontally, carried by girders at ground level and connected to a centrifugal-pump underneath by vertical shaft about 7 inches diameter, Fig. 1. The

SKETCHES AT SCHENECTADY WATER WORKS.

FIG. 1.

Electric Motor and Horizontal Centrifugal Single-Stage Pump.

Delivery, 10 million gallons per 24 hours into Town Mains at a pressure of 100 lbs. per sq. inch.



current is brought from Falls, about 20 miles away, at 10,000 volts. The motor is three-phase, the voltage being transformed down to some 550 volts, ampères 800, and the speed of motor and pump is about 800 revolutions per minute. The centrifugal-pump is about 6 feet external diameter, and raises water from an adjoining well, the level being about 16 feet below the pump. The water is pumped into mains against a pressure of 100 lbs. per square inch. There is also a small auxiliary electrically-driven geared vacuum-pump to exhaust the main pump and suction-pipe from the well for charging purposes, also a set of small electrically-driven geared three-throw pumps to pump oil at 100 lbs. per square inch under the upper collar-bearing of motor on which the weight of the armature, shaft, and pump-disc all hang, so that the whole of moving parts are floating on an oil step-bearing above (*see* enlarged sketch, Fig. 1, page 23). The pressure of oil in the annular space between the two bearing-discs just eases them apart and takes the whole weight (amounting to several tons) of working parts.

The water to be pumped amounts to 10 million gallons (U.S. gallons *) per 24 hours, which works out about 500 P.-H.P. It is only fair to say that the pump was not connected through to the town mains, and when seen was pumping against a closed valve; the vibration and noise were however abnormally great.

Cincinnati Water Works.

Messrs. R. D. Wood and Co., Philadelphia, have at present under construction in their works four sets of 1,000-H.P. vertical triple-expansion jet-condensing pumping-engines for these water works. They are 98 feet high, the low-pressure cylinder is 82 inches diameter by 8 feet stroke; speed 16 revolutions (= 256 feet per minute); two flywheels on each engine 24 feet diameter (in 8 segments); boiler-pressure 160 lbs., Corliss valves placed in cylinder-covers of high-pressure and intermediate cylinders; the valves in the low-pressure cylinder of poppet type; steam-receivers and reheaters between the cylinders.

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* United States gallon = $\frac{5}{6}$ British Imperial gallon.

The pumps have to force against 100 lbs. per square inch; duty to be between 160 and 170 million foot-lbs. per 1,000 lbs. steam; the air-pumps and feed-pumps are driven by the main engines. They are provided with vacuum-destroyer and drop-governor, and the weight is about 1,500 tons per set. The suction- and delivery-valves of the large pumps have rubber discs backed by brass spring round section, and there is a large number of $3\frac{1}{2}$-inch diameter valves.

SKETCHES AT PHILADELPHIA WATER WORKS.

FIG. 2.

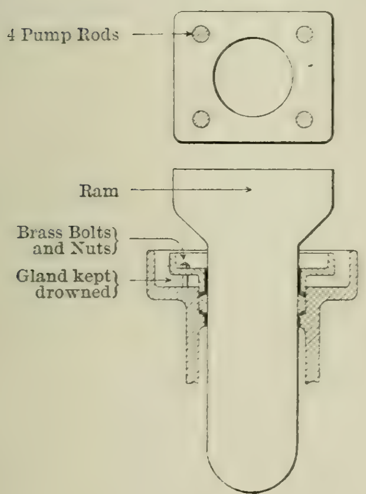
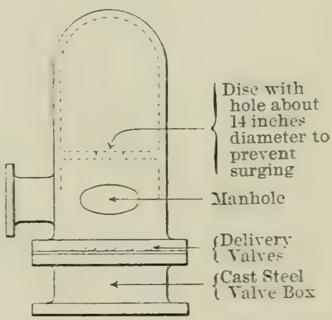


FIG. 3.



PHILADELPHIA WATER WORKS.

(New Pumping Station.)

There are three sets of vertical triple-expansion engines, with three ram-pumps, each set to pump 20 million gallons (U.S. gallons) against 80 lbs. per square inch. The low-pressure cylinders are 96 inches diameter by 5 feet 6 inches stroke; Corliss valves; pump-rams 33 inches diameter, glands kept "drowned" (as shown by rough sketch, Fig. 2); valve-casings (pump) and specials are all tested to 300 lbs. per square inch. A heater is interposed between

the low-pressure cylinder and the jet-condenser to heat the feed-water. The air- and feed-pumps are driven by the main engine. Duty specified to be 160 million gallons per 100 lbs. coal, or 1,000 lbs. steam, and boiler-pressure 160 lbs. per square inch. Crank-shafts are built of steel. The suction side of the pumps is under a head of about 20 feet. Pump-valves (multiple) about $4\frac{1}{2}$ inches diameter, usual type with rubber disc backed by a spring. Each pump delivery-chest has an air-vessel on top kept charged by Westinghouse air-pumps. The air-vessel has a disc cast inside with hole about 14 inches diameter, said to be for the purpose of preventing surging in air-vessel, Fig. 3 (page 25). Each engine weighs about 1,000 tons. The engine-house is a fine building, with 30-ton overhead electric crane, 80 feet span.

Pittsburg Water Works.

(A) *Herron Hill Sub-Station.*—All the three sets of pumping engines at Herron Hill Sub-Station were made by the Allis-Chalmers Co., Milwaukee. With the two small sets the speed is 40 revolutions; two flywheels (four bearings), 2 feet 6 inches stroke; Corliss valves, all having trip cut-off; cast-iron columns A shaped with guides fore and aft; steam 150 lbs. Suction is under a head of 35 lbs. and pumping against 80 lbs.; so that there is only 45 lbs. on pump, that is, the work done is against 45 lbs. The engines work smoothly and quietly, and cannot be heard in the street 20 yards away. The two end-cranks are overhung, Fig. 4, with four rods down to the pump-heads (that is, to rams of pumps); these two smaller engines were made in 1895. The centre crank, which is double-web, has a peculiar arrangement on one end of the crank-pin, Fig. 5. One web of crank has a square hole and one end of crank-pin fits into the square block, which has about $\frac{1}{4}$-inch clearance at each end. The object is, that should one part of crank-shaft wear more than another it allows a little accommodation, and the adjustment is easier when erecting engines. The largest of the three engines had just been at work for a few months and was not yet taken over. All admission valves are Corliss, also the exhaust on high-pressure and intermediate, but the exhaust valves on low-

pressure are poppet valves—that is, equilibrium valves of the Cornish type. The Corliss valves are all in the cylinder covers (top and bottom), consequently the cylinder itself is a very simple casting. The stroke is 3 feet, three hollow A columns; suction air-vessel on each pump. The reason for this last is that the engines draw from the town mains, and pulsation is minimized. The suction is under 25 lbs pressure; delivery at 130 lbs., 33 revolutions, plungers 18 inches diameter, and the tops of plungers are loaded so as to balance the reciprocating parts of the engine. The cylinders are 20 inches, 36 inches, and 56 inches diameter. The pumps have a delivery air-

SKETCHES AT PITTSBURG WATER WORKS.

FIG. 4.
Crosshead and Plan of Rods.

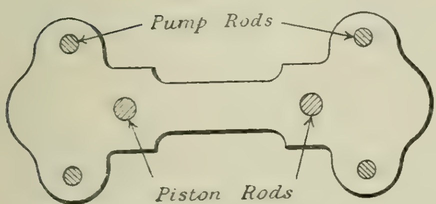
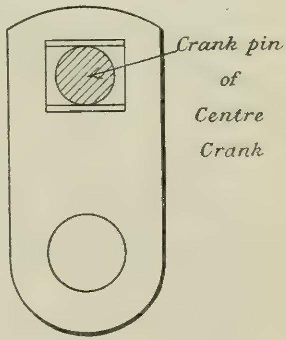


FIG. 5.
Adjustment.



vessel above each set of delivery valves, and these three air-vessels are all equalised by a pipe 12 inches or so in diameter. The pump valves (of the usual rubber disc spring loaded type) are placed in a large disc about 4 feet diameter and are in cages. Air-pumps, feed-pumps, and air-compressor pump are all overhung from crosshead of low-pressure pump. Feed-water is passed through upper portion of tubes in surface condenser, and goes into the boiler at about 120° F. Boilers are fired with natural gas, which gives a beautiful blue flame and no smoke or ash.

(B) *Brilliant Pumping Station.*—Pumps draw from Alleghany River, which at times is very thick and muddy. Water unfiltered is

full of slime, but filters are about to be made on flats across the river, to which two steel pipes 5 feet diameter will be laid. The engine-house is a magnificent one. There are at least eight sets of very large vertical engines—not triples, but compound. All but one or two sets were built by the Allis-Chalmers Co., Milwaukee. The general features are similar to other stations, but the latest set of large cross compound have cranks at 180°; plunger pumps are single-acting, and work beautifully and smoothly, having capacious air-vessels to take up shock; the flywheels are heavy—two to each engine. The pump valve-chambers and air-vessels above form supports and stiffeners for main framing of engine, but there is a plate 3 inches or 4 inches thick inserted at top, so that any chamber can be removed by simply taking out this plate. There are two piston-rods in steam cylinders; diameter of cylinders of this latest set are 66 inches and 96 inches by 64 inches stroke. Speed about 200 feet per minute, or rather over. Duty about 140 millions. Condensed steam is used for boilers, and grease is filtered out by coke in enclosed pressure filters.

Chicago Water Works.

14th Street Pumping Station.—At this pumping station there are three pumping engines each of 15 million gallons capacity, and one of 30 million gallons capacity, all being vertical triple-expansion. The first three sets were made by the Allis-Chalmers Co., and the other set by the Lake Erie Co., Buffalo. The engines are supported underneath by heavy brick pillars on one side. The large engine (30 million gallons per 24 hours) has plungers 42 inches diameter by 5 feet stroke, Corliss valves, two piston-rods to each steam cylinder. The engine has been two years at work, and during that period had averaged $23\frac{7}{10}$ hours per diem, so that it was very rarely at rest. Jet condensing; the pumps draw from a tunnel on the same level, and this tunnel is carried out under the lake bed to an intake or "crib" about a mile or more from the shore. The air-vessels in this case are kept charged by snifter valves, which are used in preference to an air-compressor. The pumps are provided with one large suction-vessel and one large delivery air-vessel. A check-valve

(reflux) was fixed on the delivery pipe, but it is now dispensed with, as the doors in a short time were worn down off the faces. Steam at 150 lbs. pressure. Duty on test 155 million foot-lbs. per 1,000 lbs. steam. Cylinders are about 32 inches, 46 inches, and 90 inches diameter. The upper portions of the pump plungers above the stuffing-box are of wrought-steel riveted pipes. The high-pressure and intermediate-pressure valves are worked by the same eccentrics; with the low-pressure there is a separate eccentric for admission and exhaust valves. There are receivers between the steam cylinders. All the engines work quietly and effectively.

ST. LOUIS WATER WORKS.

Bissell's Point Pumping Station.—At this station three sets of triple-expansion engines, Plate 1, are being erected by the Allis-Chalmers Co., having each a capacity of 20 million gallons per 24 hours, pumping to 100 lbs. per square inch, suction under a pressure of about 15 feet head; the pumps are $33\frac{7}{8}$ inches diameter by 6 feet stroke; speed $16\frac{1}{2}$ revolutions (= 198 feet per minute); pump valve in cages inside pump casings—of the usual multiple type; 1,176 valves in each engine, seven cages in each valve casing, and twenty-eight valves in each cage. (Six pump-valve casings in all); the high-pressure cylinder of 34 inches diameter has Corliss valves, the intermediate-pressure cylinder of 62 inches diameter has Corliss admission and poppet exhaust valves, and the low-pressure cylinder of 94 inches diameter has poppet admission and exhaust valves. The valve-shaft is driven by drag crank on end of main shaft; duty about 160 million foot-lbs. of water lifted per 1,000 lbs. dry steam. No superheating; steam 140 lbs. per square inch. Air-vessels have equalising pipe (delivery); each pump has air-vessel directly on suction pipe, besides large air-vessel on end of main suction pipe. Six relief valves, each about 6 inches diameter, discharge from delivery into suction pipes capable of taking full discharge of pumps, in the event of a valve being shut accidentally (to prevent damage). An air-cushion, supplied by compressed air from same pump which supplies compressed air to air-vessels, keeps up the lower poppet-

valves on the low-pressure cylinder, and counterbalances them. The centre crank has a loose square block, the pin being fast in block. There are stays from the top soleplate to bottom one, thus making the engine entirely independent of mason work. The weight of each flywheel is 40 tons. There are four main bearings and one tail bearing. The engines work very quietly and smoothly.

General Description.—It may be interesting to add that there are three pumping stations for St. Louis Water Works:—(1) At the Chain Rocks, up the river above the city; (2) at Baden high-level pumping station; and (3) at Bissell's Point, for the lower districts. At Chain Rocks the water is taken from the river and pumped into settling basins covering an area of over 40 acres. There are four triple-expansion engines here, each capable of delivering into the basins 30 millions of U.S. gallons daily. Two duplex pumps are held for emergencies and only used when the large engines are stopped from any cause. The water in settling basins is allowed to "purify itself" by settling for about 24 to 30 hours, and is then carried into the conduit to the two high-service pumping stations, from which it is delivered into the city mains. The four engines at Chain Rocks have each three 48-inch plungers. The engines stand 70 feet high and weigh nearly 600 tons each.

At Baden High-Level Pumping Station there are six engines pumping against 140 lbs. per square inch—two delivering 10 million gallons each, and four 15 millions each.

At Bissell's Point Pumping Station there are, besides the three engines described above, three old beam and fly-wheel engines, the steam distribution valves being worked by cams. These old engines are still at work occasionally as a stand-by, but consume a much larger amount of steam per H.P. than the more modern engines.

Through the courtesy of Mr. Laird, Consulting Engineer for the City of St. Louis, the figure of consumption of steam of No. 10 engine at Baden Pumping Station is given at 10·51 lbs. per H.P. per hour (presumably *Pump* Horse Power, although it is not expressly stated whether it is Pump or *Indicated* H.P.).

SKETCHES AT DESMOINES WATER WORKS.

FIG. 7.

Holly Engine. Four Cylinders and two Pumps.

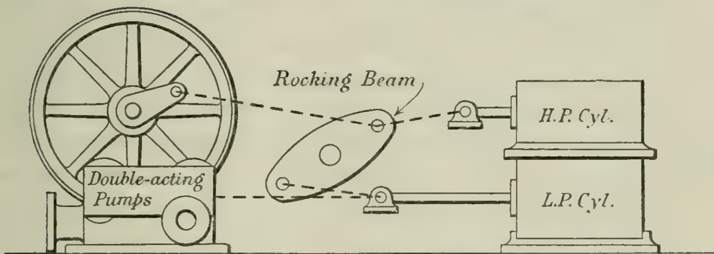


FIG. 8.

Best Position of Air-Vessel.

Air-Vessel at B was found to be more effective than where shown dotted at A.

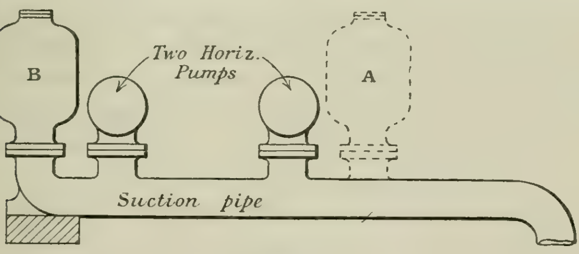
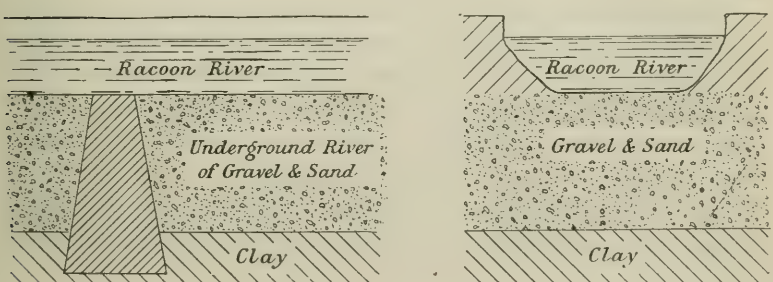


FIG. 9.

Proposed Wall to hold back underground Water in dry seasons.

Longitudinal Section. Cross Section.



Desmoines Water Works.

There are three engines—two Holly horizontal compound rotatory condensing and one Worthington horizontal. The latest Holly is double cross compound, Fig. 7 (page 31), with the high-pressure and low-pressure cylinders superposed horizontally (two of each); cylinders 24 inches and 42 inches diameter by 36 inches stroke (= 144 feet per minute); contract speed 24 revolutions per minute; Corliss valves; air-vessels have air-pump to charge them (*see* sketch showing position of suction air-vessel, Fig. 8); flywheels are in two halves; pumps with multiple valves of the usual type; suction 17 feet depth; steam 122 lbs.; water 102 lbs.; duty about 125 millions per 1,000 lbs. steam. The machines are compact, but parts look to be rather inaccessible for repairs. Valve motions are driven (1) off eccentric on main shaft for low-pressure; (2) off rocking lever gudgeon for high-pressure. The cut-off is regulated by hand, by an arrangement of bevel wheels to both sides of the engine by raising or lowering the fulcrum block carrying wrist plate for admission-valves. The water-supply for Desmoines is taken from the Racoon River, or rather it is pumped from the sand and gravel bed 16 feet or so underneath the river, Fig. 9 (page 31). Tunnels or headings, 5 feet by 4 feet, consist of wood frames having open sides (sparred) and bottom, and about 4,000 feet long (closed top). This tunnel or gallery brings water into well, from which it is pumped. The water is clear, cool, and naturally filtered. At present the gallery runs under the river bank alongside the river, but it is proposed to discard this shortly, the Corporation being afraid of sewage contamination, and have already constructed a new gallery away from the river. The remarkable thing about this underground supply is that there seems to be a river under the Racoon River, the submerged river being in a gravel bed; and this lower river flows as the upper river does. Consequently it is proposed to construct a dam under the river-bed down to the lower strata (which is clay), so as to dam back the water and give underground storage in dry seasons. At times the Racoon River is almost dry and then the underground river gets short also.

MINNEAPOLIS WATER WORKS.

At the Old Pumping Station is a Worthington high-duty compound engine; pressure 214 feet; duty about 80 millions. At the New Pumping Station, on the other side of the Mississippi River, there have just been erected and set to work two sets of Holly vertical triple-expansion surface-condensing pumping engines. The steam-valves are Corliss on the high-pressure cylinder, Corliss on the intermediate, and poppet on the low-pressure cylinder; this last cylinder has two poppet-valves on top and two on bottom; lay shaft for valve motions worked from each end by cranks at 90°. One piston-rod in each cylinder; cylinders 30 inches, $56\frac{1}{2}$ inches, and 84 inches diameter by 60 inches stroke; speed 20 revolutions, equal to 200 feet per minute; suction lift about 16 feet. Pumping against a pressure of 214 feet, surface condensing, vacuum 27 inches; the heater is between the low-pressure cylinder and the surface condenser. The water for feeding the boilers is taken from the hot-well and passed through the heater. The capacity of each pumping-engine is 15 million gallons (U.S. gallons) per 24 hours, and the guaranteed duty is 140 million foot-lbs. per 1,000 lbs. steam, but it is hoped that better results will be obtained. The centre crank has a loose block, as has already been described. The suction and delivery pipes on pumps are double, Fig. 10 (page 34), coming in and out of each side; and the suction pipes have an air-vessel on one end. The air-vessels on delivery are equalised, and help to support framing; there are three pump plungers, each $29\frac{1}{4}$ inches diameter, and the pump valves are of the usual multiple type. Each engine complete weighs about 750 tons, each flywheel 30 tons, and there are two wheels on each engine. The engines work very smoothly and quietly. Steam superheated pressure is 140 lbs. or 160 lbs. per square inch. A sketch of screening arrangement at intake from River Mississippi is added, Fig. 11 (page 34).

WINNIPEG WATER WORKS.

At these works are two sets of pumping engines, of a capacity of 8 million gallons. One engine is a compound vertical Worthington,

SKETCHES AT MINNEAPOLIS WATER WORKS.

FIG. 10.—*Suction Pumps.*
(Suction and Delivery pipes are double.)

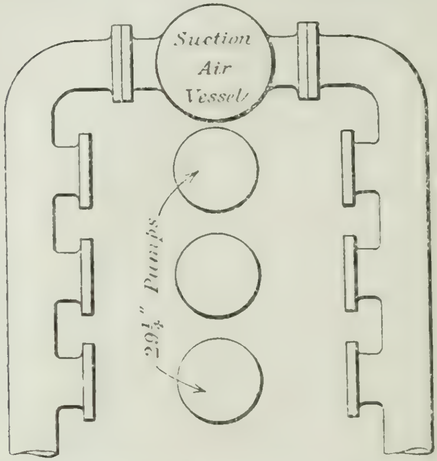
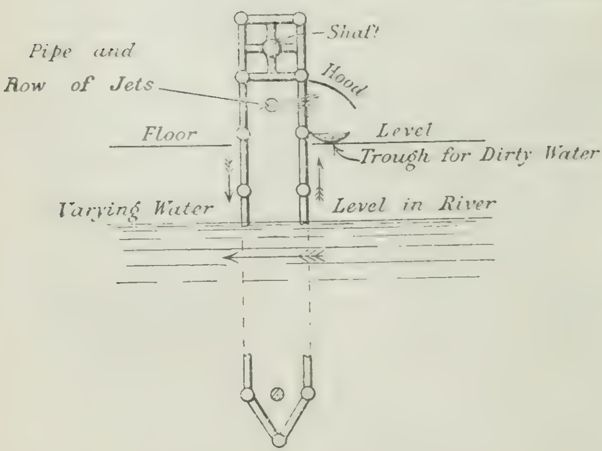


FIG. 11.—*Revolving Screens at Intake from River Mississippi.*
Four Shaft Bearings on Guide Pillar



The square frame at top revolves, and the Screens, in the form of an endless band of rectangular sections, pass over it as they reach the top. The screens travel slowly, the water-jets spraying and washing all the time, keeping screens clean.

and the other a triple. The latter has six cylinders and two pumps; cylinders 18 inches, 27 inches, and 40 inches diameter by 2 feet stroke (but working only 18 inches stroke). The pumps are 24 inches diameter and work at 40 lbs. per square inch. The pumps are double plunger and outside packed, and have a balancing ram against 90 lbs. per square inch to balance the working parts. The balancing vessel is of wrought-iron, and has an air-compressing pump to keep up the pressure, consequently it is a hydraulic balance-pump. The engine has rocking compensating cylinders, but they are not in use. The condenser is "surface" with independent duplex air-pump. Duty said to be 80 millions; steam 100 lbs.; multiple pump valves; steam valves, Corliss; engine works very quietly. The pressure for compensating rocking cylinders is given by a differential accumulator. One end is loaded with pressure from the mains, and the other end gives 90 lbs. for compensating. The water is very hard and is softened by Clark's process. The water is pumped from a well about 12 feet under the surface to a tower, by a separate pumping-engine; it then gravitates from the tower through a filtering press, &c., and runs into a clear water tank (softened), whence it is picked up by the main pumps. The softening is said to cost three cents per 1,000 gallons. In order to ensure that there is no free lime in the supply to the town, CO_2 is passed from a coke furnace through the water, which sprays from boxes with perforated bottoms, and this dissolves any free lime. The softened water is clear as crystal, and the hardness is said to be reduced from 50° to about 7°. They have on order at the present time a set of double stage centrifugal pumps to be driven by a motor at 210 volts; and an old engine is being adapted for this work. The centrifugal is to pump against 80 lbs. and to run about 1,200 revolutions. A new well about 20 feet diameter is being sunk down 60 feet to the limestone.

Toronto Water Works.

The older engines are one of 8 million gallons capacity and one of 5 million gallons capacity, cross compound duplex Worthington; these are about 20 years old; steam 60 lbs.; water 90 lbs.; pumps

double-acting (in sleeve) 24 inches diameter by 3 feet stroke; duty about 40 millions. The two newest engines are Holly horizontal cross compound rotatory; steam 100 lbs.; water 90 lbs.; cylinders 28 inches and 56 inches diameter by 4 feet stroke by 32 revolutions, which is equal to 256 feet per minute, but often run up to 300 feet per minute; duty about 100 millions; surface condensing; vacuum 25 inches; air-pump independent duplex. The style is like the Desmoines engine; suction about 12 feet; cylinders jacketed and with reheater between them. They are at present making foundations for a new triple surface condensing engine, being made by the John Inglis Co. of Toronto—piston speed 200 feet per minute to pump against 100 lbs. per square inch; stroke 5 feet; duty specified is 165 millions * per 1,000 lbs. "commercially dry" steam; steam pressure 150 lbs. per square inch. Capacity 15 millions Imperial gallons per 24 hours. Area of clear waterway of pump valves specified to be 180 per cent. of plunger area; steam cylinders to be jacketed and fitted with reheaters.

London (Ontario) Water Works.

Their supply is from beautiful springs—pure clear hard water, and is pumped to the reservoir against 105 lbs. by two sets of horizontal double-acting pumps, 18½ inches diameter by 2 feet stroke by 24 revolutions. Two pumps in each set, four pumps in all. These are driven by two turbines which get water-power from a weir on the river, 10 feet fall (about 150 H.P.). They have also two sets of horizontal compound (cross) pumping engines condensing (jet) as a stand-by when water-power fails.

Boston Water Works.

Chestnut Hill Pumping Engines.—From want of time, the author regretted that he was unable to see these engines at work. They are, he understands, among the best examples of pumping engines in the

* This is a very high specified duty—a more recent figure being 140 millions for engines of 12 millions capacity (Imperial gallons).

United States, Fig. 12, Plate 2. Capacity, 30 million U.S. gallons per 24 hours. Diameter of cylinders, 30, 56, and 87 inches. Stroke, 66 inches. Steam pressure, 185 lbs. per square inch. Average dry steam per I.H.P. per hour = 10·335 lbs. Duty, 178,497,000 foot-lbs. per 1,000 lbs. of dry steam. Thermal efficiency of engine, 21·63 per cent.

General Remarks.—In Great Britain the duty of pumping-engines is usually expressed in foot-lbs. of water lifted per 112 lbs. of best Welsh coal. In the United States and Canada this duty is given as per 1,000 lbs. of dry steam. In the United States the gallon employed is the "United States gallon," equal to five-sixths of the Imperial gallon. In Canada the Imperial gallon seems to be usually employed.

The author is indebted to Mr. Arthur Warren, brother of the President of the Allis-Chalmers Co., of Milwaukee, for the figures given for the Boston 30-million pumping engine, who has also kindly sent a photograph of this engine, Plate 2; also for a photograph of Bissell's Point Pumping Engine, St. Louis, Plate 1. He is also indebted to Mr. John A. Laird, consulting engineer of the City of St. Louis, for some notes on pumping engines at Chain Rocks and Baden Pumping Stations of that city.

The Paper is illustrated by Figs. 6 and 12 on Plates 1 and 2, and 10 Figs. in the letterpress.

Discussion on 20th January 1905.

The PRESIDENT asked the Secretary to inform Mr. Barr of the applause that had greeted the reading of his Paper, which indicated the members' appreciation of it.

Mr. Edward C. R. Marks said he was sorry the author was not present, because there were a few questions he would like to put to him concerning the figures that had been given of the duty which was obtained from the various pumping engines described in the Paper. First of all, he would like to ask if the figures were official figures, or only such figures as were obtained at the Exhibition itself, concerning the duty of the pumps and the pumping plant, for dealing with the water for the cascades. The official guide-book said it was the largest pumping plant ever known, and that the water dealt with was the largest volume of water ever put in motion by artificial means. After reading the guide-book he naturally looked out for that wonderful pumping plant, and with some considerable trouble found it. The actual figures worked out as follows: The great pumping plant consisted of three centrifugal pumps, each of which was direct-coupled to a Westinghouse motor. The impeller was in each case 5 feet, and the suction and the delivery 36 inches. It was a size which an English maker would consider quite small, and not worth talking about for a single moment. But the official guide-book gave quite a poem on the wonderful volume of water (said to be 90,000 gallons per minute) which was put in motion by means of these pumps. The pumps were rated at 35,000 gallons per minute apiece; but when he got to the Exhibition he found that only one was at work, and that was not giving more than 30,000 gallons. He enquired when two or the three were to be set to work, and was told that two had been put on once, but after a short run they had to be stopped, as the authorities were afraid of bringing the whole place down about their ears. Consequently, throughout all the time he was there, only the one pump was working, and the official 90,000 gallons was at once reduced to 30,000 gallons. He wished to ask if the figures which were given in the Paper were so unreliable as those with which he (Mr. Marks) had had to deal. The pump horse-power or effective horse-power of the one pump which he saw at work was 670, but the amount of work put into the motor was 1,120 H.P., giving a mechanical efficiency of 60 per cent. He was sure Mr. Davey would smile at an efficiency of that kind.

In dealing with the St. Louis pumping station, and with several others, Mr. Barr stated that he "was informed." He (Mr. Marks) wished to bear out fully the remark of Mr. Charles Wicksteed, that everyone had to take much of the information offered them in America with considerable caution. Mr. Barr said that he was informed (page 30) that the engine at the Baden station was using 10·51 lbs. of steam per H.P., and presumed it was P.H.P. He (Mr. Marks) was certain it was not P.H.P., because if it were, it would give a duty of 188,000,000 foot-lbs. per thousand lbs. of steam, and he was perfectly certain that that had not yet been done either in America or in any other country. They were also informed (page 37) that at the Boston works, at Chestnut Hill pumping station, there was a duty of 178,497,000 foot-lbs. per thousand lbs. of dry steam, which worked out at 11·1 per P.H.P. That happened to be the very station with regard to which a few years ago they were told a great deal about a Riedler pump, which was put down there. He would like to ask if that Riedler pump was now on the scrap heap, or what had happened to it. Some members had heard much about that pump, and the figures published on this side concerning it. With regard to size, it happened to be about the same as a pump which was now at work in Leeds, of which Mr. Davey could say a good deal. The pump or pumping engine at Leeds was a triple-expansion vertical type, with 15, 25, and 40-inch cylinders, and a 3-foot stroke, having a piston speed of 217 feet a minute. It gave a duty, on a test made by Professor Unwin, of 151,670,000 foot-lbs. effective work per thousand lbs. of steam The Chestnut Hill Riedler type pumping engine—of which Mr. Barr said nothing, and therefore it must be presumed to be on the scrap heap at the present moment, although it was only ten years old—was tested by Professor E. F. Miller and gave 158,147,000 foot-lbs., or about 4 per cent. better than the result at Leeds. But to get that 4 per cent. difference they had to raise the steam from 138 lbs. to 176 lbs., and had to run the pistons at a speed of 607 feet as against 217 feet per minute. It seemed to him they had got the extra 4 per cent. at much too great a price, and they would have done far better had they purchased a pumping engine from this side, notwithstanding the terrible duty which they would have had to pay to get it into their country.

Mr. Edmund L. Morris said he always liked, if possible, to stand up for the "Old Country," and thought the figures which were given in the Table (page 41) showed that the engines made in England were quite as good as those built in America. He remembered a Paper by Mr. Teague on a new engine put up at the Lincoln waterworks* being read at the Institution eighteen years ago. It was a Cornish engine, and the chief point of discussion at that Meeting was the comparative merit of the Cornish and the rotatory engine. Mr. Mair-Rumley mentioned that a rotative engine might be expected to work at from 18 to 20 lbs. of steam per I.H.P., against 26 lbs. for the Cornish engine. He thought much progress had been made since then. He remembered saying at that Meeting that he considered a triple-expansion engine working three pumps would make a very good pumping engine, on account of its giving a very uniform flow of water. Several engines of that class had since been put up in London. The benefits of the overhead triple-expansion engine system were fully appreciated. Such engines had been put up by the East London Water Co., by the Southwark and Vauxhall Water Co., by the Grand Junction Co., and by the New River Co. The New River Co. had now put up eleven engines of that type: one at Hornsey, two at Clerkenwell, three at Cricklewood, and five at Kempton Park. He had a list of triple-expansion engines, which had been obtained principally from published results, and he believed that the engine put up at Waltham Abbey in 1890 was about the first of that description. The steam per I.H.P. was 15·4 lbs. An overhead triple Worthington engine was put up for the West Middlesex Co. in 1896, which used 15·1 lbs. of steam per I.H.P. At the New River Head, No. 1 engine, put up in 1899, used 14·9 lbs. of steam per I.H.P. Then a New River horizontal Worthington triple used 14·2 lbs.; a Southwark and Vauxhall engine at Hampton, tested in 1901, used 14 lbs.; and another New River Head engine, No. 2, put up in 1903, used 13·7 lbs. He believed an engine at Liverpool—he did not quite know the date—used 12·7 lbs., and the Lea Bridge engines, he believed, worked at 12·5 lbs. of steam per

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* Proceedings 1887, page 124.

Trials of an Overhead Triple-Expansion Pumping Engine.
March 1904. *New River Water Works, Hornsey.*

Cylinders, 21, 34, 52 inches diameter. *Stroke*, 48 inches.
Pumps, 27 or 18½ inches telescopic plungers.

Plungers in use.	27 inches.	18½ inches.
Duration . . . . hours	12	10
Gallons pumped	5,377,000	2,123,045
Head. . . . . feet	113·8	267·7
Revolutions per minute	25·1	25·4
Steam Pressure at Engine . . . . lbs.	155	155
Pump Horse-Power	257	287
Indicated Horse-Power	294·5	326
Mechanical Efficiency. . . . . per cent.	87	88
Total Dry Steam per P.H.P. per hour . lbs.	13·3	13
Total Dry Steam per I.H.P. per hour . lbs.	11·6	11·5
Duty per 1000 lbs. of Dry Steam	148,800,000	152,300,000
Duty per 112 lbs. of Coal at an Evaporation of 10	166,700,000	170,600,000

I.H.P. The Chicago engines—Allis engines, 1903—brought the figure down to 12·1 lbs. The Milwaukee engine, which he believed was the lowest on record up to the date of its trial in 1893, used 11·8 lbs. of steam per I.H.P. The Hornsey engine, No. 7, Figs. 13, 14 and 15 (page 42–44), the results of which were shown in the Table (above), was tested about eight or nine months ago, and brought the figure still further down to 11·5 lbs. of steam per I.H.P.

Coming to the two engines described by the author, he thought they were the only two triple-expansion engines in the Paper of which any tests had been given. Most of the duties stated, as far as he could ascertain, were specified duties only, but the engines, with the exception of the two large ones, had not yet been tested. The Chicago engine with 1,000 H.P. worked out at about 11·3, or a duty

(Mr. Edmund L. Morris.)

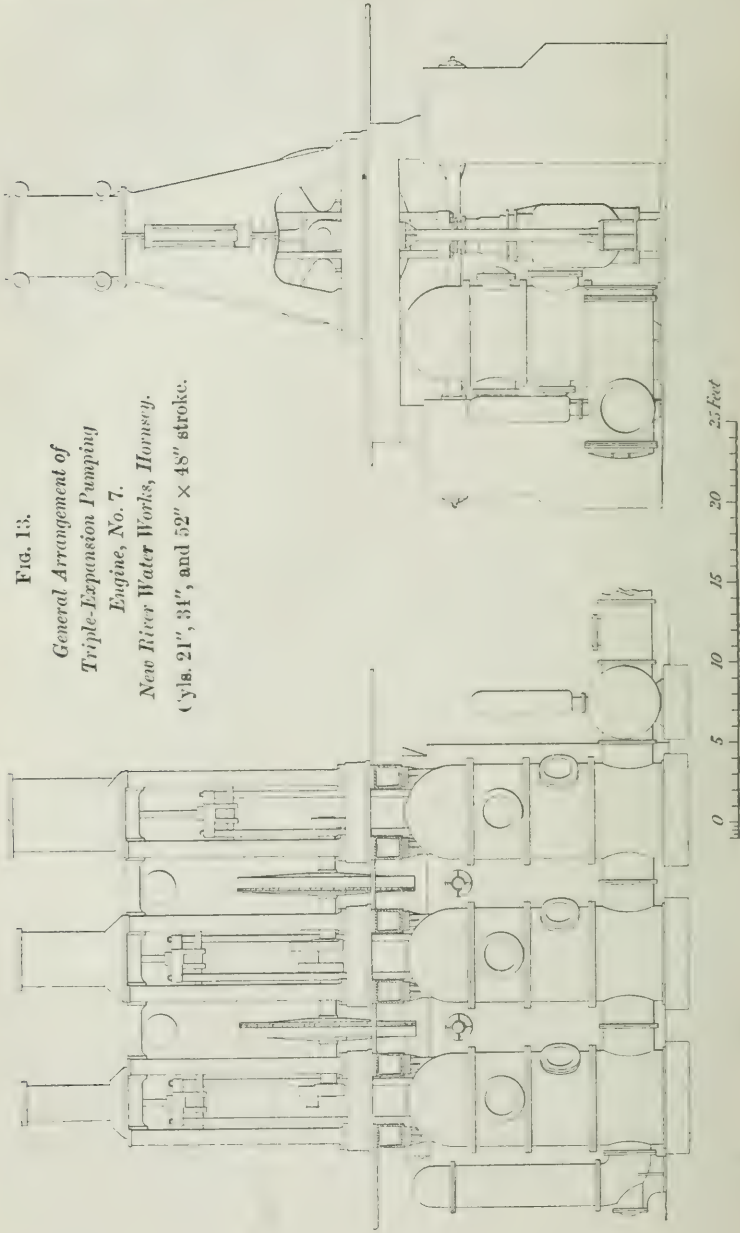


FIG. 13.

General Arrangement of Triple-Expansion Pumping Engine, No. 7.

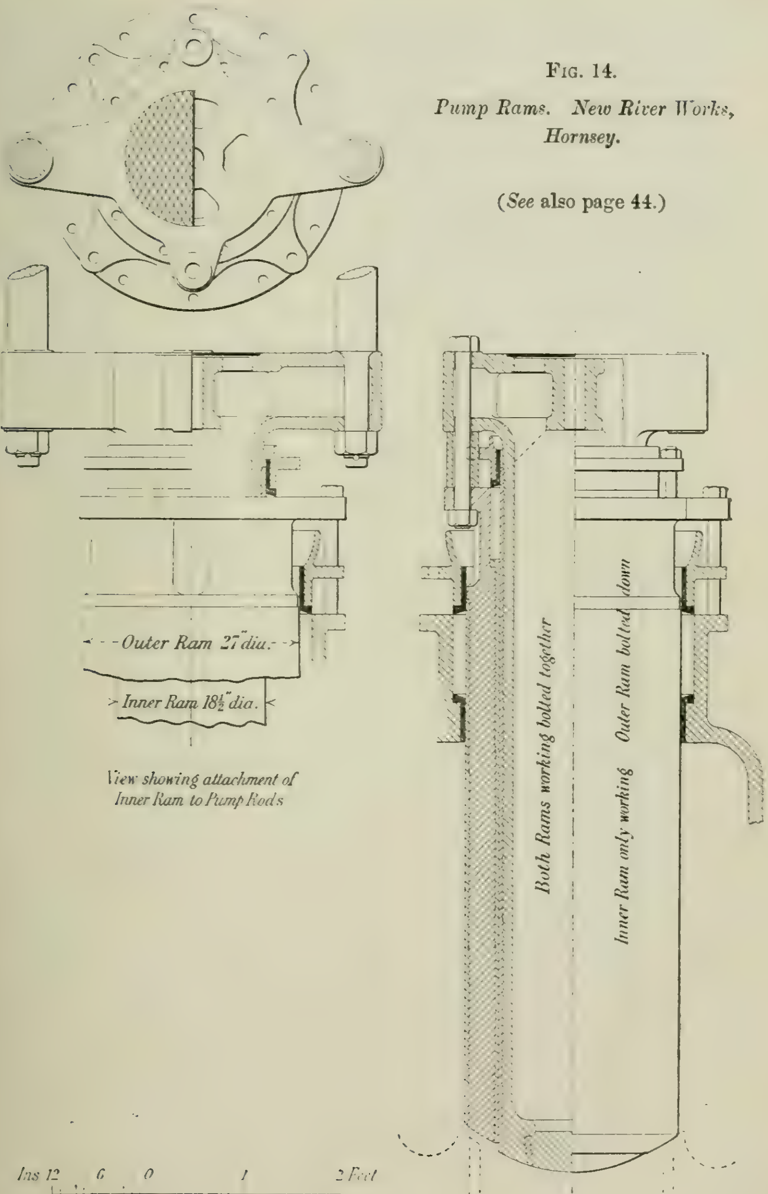
New River Water Works, Hornsey.

Cyls. 21", 34", and 52" × 48" stroke.

FIG. 14.

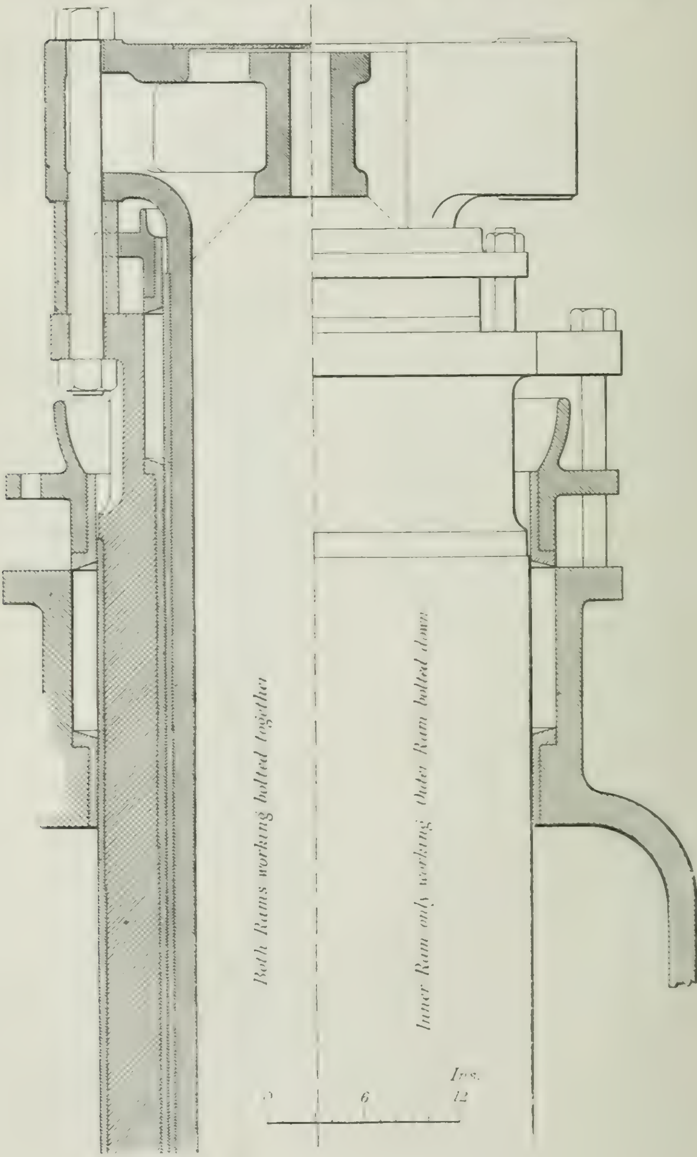
Pump Rams. New River Works, Hornsey.

(*See* also page 44.)



(Mr. Edmund L. Morris.)

FIG. 15.—*Enlarged View of Pump Rams. New River Works, Hornsey.*



of 155 millions per thousand lbs. of steam. The Boston engine, which was another very large engine, gave 10·3 lbs. of steam per I.H.P., or 178,400,000 foot-lbs. duty per thousand lbs. of steam.

The Hornsey engine was an ordinary triple, working three plunger-pumps, but it had to work to two reservoirs at different levels, so that each plunger was divided into two, or rather each pump had two plungers working telescopically one inside the other, the larger plunger of 27 inches working to the lower level reservoir, and the smaller plunger inside that, $18\frac{1}{2}$ inches diameter, working to a higher level reservoir. Working at the same speed and at about the same H.P. it could pump either 10 million gallons per day of 24 hours to a height of 124 feet, or $4\frac{3}{4}$ millions to a height of 270 feet. There were air-vessels as described by the author on each delivery. There was a suction air-vessel at the end of the suction main, and a surface condenser on the suction pipe on the way to the pump. Fig. 3 (page 25) showed a diaphragm in the air-vessel, which was put there to prevent surging. In this case, however, the water rushed up and down in the small hole in the centre of the diaphragm and absorbed the air in the air-vessels, and carried it away into the main. Various devices were tried—baffle-plates and internal deflection pipes—but without success, and the hole was gradually enlarged until the whole of the baffle-plate was cut away, and no further trouble was experienced. It had two fly-wheels, overhung cranks, and a sliding block for the crank-pin in the centre crank. It had trip-gear to all the cylinders, which were steam-jacketed and fitted with reheaters. He was not quite certain about the efficacy of the reheaters. In two instances lately he had found that an engine working without the reheater had given results equally as good as when the reheater was in use, but he presumed that depended on the circumstances under which the engine worked. It would be interesting if the author could give the results of the trials of the other engines which he had mentioned; later on perhaps he would be able to do so. It might be noticed that the low-pressure cylinders were mostly fitted with poppet valves instead of Corliss valves, and he presumed there was some good reason for that. Very few of the engines appeared to be fitted

(Mr. Edmund L. Morris.)

with surface condensers, and he supposed there was also an equally good reason for that, which perhaps the author would be able to explain.

Discussion on 17*th February* 1905.

Mr. A. H. MEYSEY-THOMPSON thought a debt of gratitude was owing to Mr. Barr for bringing before the Institution the performances of American pumping engines, more especially as applied to the triple-expansion engine. That engine had a particular interest for Englishmen, because it was originally developed on the sea, and he believed the first person to apply it to pumping machinery was Mr. Bryan at the East London Water Works, nearly twenty years ago. Since that time the triple-expansion engine had been largely modified and improved on both sides of the Atlantic, and in bringing before the Institution the modifications which had been made in America Mr. Barr had performed a great service. To criticise some of the points which had been brought forward, Mr. Morris had drawn attention to the fact that a poppet valve was put on the low-pressure cylinder and a Corliss valve on the high-pressure and intermediate pressure. That was a reversal of continental practice. Germans argued that if a rubbing surface was put anywhere it should be on the low and intermediate, and that a poppet should be put on the high-pressure cylinder when dealing with superheated steam. In his own practice he had always put Corliss valves on all three, and had found no difficulty at all in the matter. He desired to ask Mr. Barr if he knew why the Americans had reversed the continental practice.

The author had also drawn attention to the fact that air-vessels were provided both on suction and delivery pipes, and that it was a common practice to have an air-vessel along the top of each delivery valve, but he had said nothing about a vacuum vessel being placed below each suction valve. That was a practice which he (Mr. Meysey-Thompson) adopted with very beneficial results. He did not think that the method with a vacuum vessel at the end (page 34)

was anything like so good, because a much better pump diagram was obtained when the vacuum vessel was attached to each pump than when there was only one vacuum vessel at the end, upon which all three pumps had to depend for equalising the pressure.

On page 22 in paragraph 8 the author said that the centre crank-pins of large pumping-engines had one end in a square block carefully fitted into a slot in the web of the crank on one side to allow "accommodation," and the illustration farther on showed that block (page 27); but Mr. Barr made no mention of any adjustment, and he himself certainly had found that adjustment was very necessary to take up wear. He also did not see why a square hole had been adopted. In his own practice he used a round hole, which was much better and stronger and kept the crank stronger, and it was a much easier thing to fit accurately a round hole than a square one. He did not quite understand why they should take the trouble to make a square hole for that pin to go through. He had used the round hole for years and had found it an excellent arrangement, allowing as it did for any little settling that might take place owing to the wear on the bearings, and thus avoiding any straining of the crank-shaft if the engine should happen not to be put quite in line.

Then, again, with regard to duties, it had been the custom on the part of a great many writers, especially those not very well informed, he thought, to assume that American duties were very much better than anything obtaining on this side of the water. It was true that there had been some very exaggerated statements made by Americans, but it was also true that there had been some exceedingly good duties obtained. But when one took into consideration the size of their engines—several mentioned in the Paper going up to 1,000 H.P.—and the much smaller engines that, as a rule, were in use in this country, he thought those in this country compared very favourably with the American ones. In a little engine at Leeds, tested by Professor Unwin—an engine which only indicated 184 H.P.—a consumption of 13·05 lbs. of steam per P.H.P. gave a mechanical efficiency of 91 per cent. Since then an engine of 232 I.H.P., built in Leeds, had been running at Rosario which consumed only 12·28 lbs. of steam per P.H.P., and gave a duty of 161,250,000 foot-lbs. per 1,000 lbs. of

(Mr. A. H. Meysey-Thompson.)
steam, with a mechanical efficiency of over 90 per cent. He thought those mechanical efficiencies were about as good as anything Americans had shown. The steam per P.H.P. was slightly better, but when comparing an engine with 200 or 300 H.P., with an engine with 800 or 1,000 H.P., it might be presumed that the smaller engine was doing very well when it came so near to the results obtained by the much larger American one.

Mr. C. LIDDELL SIMPSON, who had seen some of the engines which had been described in the Paper, agreed with what Mr. Meysey-Thompson had said about the Americans having opportunities for building much larger engines than were usually adopted in this country for pumping. There were very few pumping engines in England as large as 600 H.P.; there were a few of 500 H.P., but the majority of them were either 100, 150 or 200 H.P. With regard to air-vessels and suction air-vessels, each case had to be taken into special consideration. There were some cases where suction air-vessels were necessary, and some where the engines would run quite well without. It was impossible to lay down any hard and fast rule as to whether they were always necessary; every case had to be taken by itself.

Referring to the arrangement of the adjustable crank-pin on the engines at the Herron Hill sub-station of the Pittsburg Water Works, this was nothing new, and had often been adopted; his own firm, Messrs. James Simpson and Co., had in several cases of crank and fly-wheel engines fitted a sliding block into the centre crank. They had made it a sliding adjustable block which could be got at and would permit of a little give and take in the crank-shaft; and Messrs. E. P. Allis on their power engines at the Glasgow Tramway Power Station at Pinxton, used the same adjustment on the crank-shaft. With regard to the Chicago Water Works, only the 14th Street Pumping Engines were mentioned, but there were a great number of other sub-stations with large pumping engines—for example, the six sets of high-duty vertical Worthington pumping engines at the Central Park Avenue and Springfield Avenue Pumping Stations, Chicago, which were made by Messrs. Henry R. Worthington

of New York. These had a capacity of about 22,000,000 gallons (U.S.A.) each per 24 hours. The cylinders were 21 inches high pressure, 33 inches intermediate and 60 inches low pressure, with 34½-inch plungers, and all having a 50-inch stroke. The weight of the moving parts was balanced in a very simple manner with a special arrangement of air balance. On trial, these engines gave a duty about 160 to 170 million foot-lbs. per 1,000 lbs. of steam, the boilers being fitted with the "Foster" type of superheater. He considered that this was one of the best duties that had been obtained on a direct-acting engine—that was, one not controlled by a crank and fly-wheel. In 1904 an order was placed with Messrs. Henry R. Worthington for two additional vertical high-duty Worthington pumping engines, each having a capacity of 40,000,000 gallons (U.S.A.) per 24 hours, which indicated that the direct-acting engine still held its own as one of the best engines for economically pumping large quantities of water.

Turning to this country, a small vertical high-duty Worthington pump had been built by his own firm, but it was only about 125 to 130 H.P. and the cylinders were 12 inches, 20 inches and 34 inches with a 24-inch stroke and a 13½-inch plunger. It was a vertical engine balanced exactly in the same way, and its capacity was 2½ million gallons per twenty-four hours with 12·2 lbs. per P.H.P. per hour with 150° F. superheat. That, he thought, was a very good result for a small engine. His firm had also built 20 high-duty Worthington engines for Coolgardie. The best trial they had got out of them was just under 12 lbs. per P.H.P. per hour with about 100° to 120° F. of superheat. The power of the engine was about 300 H.P. The point he would emphasize was that he felt sure that if water works or corporations would give English manufacturers a chance of building pumping engines of 1,000 H.P., such as were built in the United States, just as good results would be obtained. In America the towns were very wasteful with the amount of water that was given them, and a great number of them used as much as from 80 to 100 gallons (U.S.A.) per head. The figure in this country, as was well known, was 30 to 33 gallons per head. That made a very great difference,

(Mr. C. Liddell Simpson.)
and was the reason, or one of the reasons, why they had such large engines in the States.

Mr. JOHN BARR, in reply, thanked the members for the free and frank discussion of his short Paper. He ought perhaps to explain that while in America he had no intention of writing a Paper on the subject of American Pumping Engines; and it was only when he was asked to put his notes on the subject into the form of a Paper for the benefit of those who had been unable to join in the meeting that he had added a few general observations to give them the dignity of a Paper.

In reply to Mr. Marks, he was sorry he did not see the centrifugal pumping engines which raised the water for the cascades at the St. Louis Exhibition. There was so much to see in the short time at his disposal that some things had to be omitted. He therefore could not say how they did their work; but a similar pump at Schenectady Water Works, which he did see at work, was a little disappointing, as the vibration and noise were abnormally great; but it was only fair to say that the pump was working against a closed valve and possibly the performance of the pump when pumping into the mains might be better.

Referring to the figures given in the Paper, on the reliability of which the speakers seemed to throw some doubt, he could only say that they were given to him by the officials whom he met and who were in a position to give correct information. The figures with reference to the engines for Cincinnati were given by the makers, and he understood them to say their guarantee was 160 millions, but that they had good reason to expect a duty on trial of from 160 to 170 millions. The Philadelphia engines were almost ready to set to work, and the Assistant City Engineer stated that 160 millions per 1,000 lbs. of steam was the duty specified. At Pittsburg the City Engineer himself informed him that the large vertical compound engines at Brilliant pumping station gave a duty of about 140 millions. In conversation he expressed the opinion that, had the engines been triple-expansion, a considerably higher duty would have been possible. In Chicago the engineer in charge at 14th

Street Pumping Station stated that the engine gave 155 millions on a test run. In St. Louis, at Bissell's Point Pumping Station, the engineer in charge of the erection of the new engines, one of which was at work, informed him that 160 millions had been obtained on a trial run, and that a considerable premium would be due to his firm for exceeding the duty specified. At Minneapolis the engineer who accompanied him to the pumping station said that the guaranteed duty was 140 millions. Coming now to the Toronto Water Works, he had with him a specification of the new triple-expansion engines, and the duty specified was 165 millions, under a penalty of £400 for each million under the 165 millions specified. He also held a specification of a new triple engine for the Montreal Water Works, and the duty specified was 140 millions, the engine being smaller than the Toronto one. The information given at the foot of page 30, referred to by Mr. Marks, was furnished by Mr. John A. Laird, consulting engineer of the City of St. Louis. It was possible Mr. Marks might be quite right in considering the 10·51 lbs. to be per *Indicated* H.P. If it was really *Pump* H.P. then the duty would, as Mr. Marks stated, run up to over 188 millions, and it therefore looked as if *Indicated* H.P. was what Mr. Laird meant.

With regard to the duty of the Boston pumping engine referred to in the Paper (page 37), the figures given were, as mentioned, furnished by Mr. Arthur Warren of the Allis-Chalmers Co. As to the reliability of the figures, he thought he had given ample evidence of their trustworthiness. He was not interested in extolling American results, but he did consider that what he had stated were results which had been actually got and given on the word of gentlemen whose truthfulness he believed to be unimpeachable. He did not see or hear anything of the Riedler Pump referred to by Mr. Marks; but he was not able to gather from Mr. Marks the reason why he doubted the correctness of those American results when he informed them in the same breath that a triple-expansion engine at Leeds gave a duty of fully $151\frac{1}{2}$ millions—a splendid duty of which all ought to be proud, when it was considered that the engine was a comparatively small one. It seemed to him that the Americans had probably greater experience and certainly more opportunity of

(Mr. John Barr.)
putting down large triple-expansion pumping engines than we had on this side. He did not doubt for a moment that, given a similar opportunity, the American results could be surpassed.

Coming now to the remarks of Mr. Morris (page 40), who he was glad to see stood up for the "Old Country," he was certain that the members of the Institution were greatly indebted to him for the splendid array of figures he had given for pumping engines at home; and he thought that, if his own little Paper had done nothing else but bring those home performances to light, it had effected a good purpose. The members were much obliged for the full particulars Mr. Morris gave of the Hornsey pumping engines. Regarding the diaphragm in air-vessels, he mentioned that because it was new to him. As to reheaters, they were not uncommon in America, but one American engineer, who had great experience, expressed just what Mr. Morris found at Hornsey, namely, that the reheaters did not seem to be of much benefit; but he also stated (and this might perhaps interest the members) that as regards jacket steam, the best results had been attained by using steam at boiler pressure in the high-pressure jacket, steam at high-pressure exhaust pressure in the intermediate jacket, and steam at intermediate exhaust pressure in the low-pressure jacket. The reason why poppet valves were used in the low-pressure cylinders in the large triples seemed to be that large ports and small clearances were easily got by using poppet valves.

On the question of the engines being jet or surface condensing, Cincinnati was jet condensing, Philadelphia was jet condensing, Pittsburg was surface condensing, Chicago was jet condensing, and with regard to St. Louis, Minneapolis and Toronto, he was not certain, but believed them to be surface condensing.

With reference to the remarks made that evening, he would first reply to Mr. Meysey-Thompson (page 46), who asked why poppet valves were used on the low-pressure cylinders. He was not quite certain on that point, but he thought it was principally because the large engines, with low-pressure cylinders of about 90 or 94 inches diameter, required very large ports indeed, and some of them had two poppet valves in the top and two in the bottom, the reason being

that they got small clearances and large areas. Regarding suction air-vessels with suction valves, the vertical type of engine did not lend itself very readily to suction air-vessels directly above the valve, because usually the suction valve was right underneath the delivery valve. Mr. C. Liddell Simpson had remarked that the positions of air-vessels depended altogether on circumstances, and he thought that was right, because in several cases in America the suction came in under a pressure. In many other cases the engines drew their water 8, 10, or 12 feet, as the case might be, but the majority of the engines he saw had a large suction air-vessel on the suction main just before branching off to the various pumps.

With reference to the crank-pin adjustment, Fig. 5 (page 27), he thought the square block on the end of the crank-pin which worked in the slot in the crank-web would give a much better wearing surface than a round pin working in an oval hole; and no doubt this was the reason for employing the square block. With regard to the duties generally, he did not think he had said anywhere in his Paper that the American duties were better than those obtained in this country, but he thought that what had been said by one of the speakers was quite true—that the Americans had better and greater opportunities of making larger engines than manufacturers in this country, and therefore they were better able to produce higher duties in most cases. With reference to Mr. Simpson's remarks, he was not aware that the "accommodation" crank-pin had been used in this country, and was glad to hear Mr. Simpson had seen it. He did not know whether the engines, for which Mr. Simpson had given figures, referred to Chicago or not. The only pumping station he visited in Chicago was the 14th St. Station, and in that station they had vertical triple-expansion rotatory engines.

Communications.

Mr. H. F. Rutter wrote that though the Paper contained little that was new, it was not the fault of the author, but rather an indication of the fact that pumping-engine practice had for the time

(Mr. H. F. Rutter.)

crystallised in the form of the triple-expansion inverted cylinder engine with three-throw pumps. The writer had not the time to visit the States with the Institution last year, but he had made a somewhat extensive study of large pumping engines there in 1899, and had found that all the principal points referred to by the author were then incorporated in the most advanced practice. Given the necessity for the use of a reciprocating pump, the type above referred to had many obvious advantages. It might, however, be still worth while to investigate further the possibility of improvement by altering the usual arrangement of the cylinders, and coupling the low-pressure piston to the middle crank.

Touching the remarks of Mr. Morris at the last Meeting as to reheaters (page 45), his conclusion that little or no economy resulted from their use was of course amply confirmed by experiment. It might, however, be well to place on record the fact that the use of reheaters did add appreciably to the capacity of the engine.

The remarks as to steam consumption claimed by rival manufacturers might perhaps be amplified as followed. Tests made by many independent authorities might without doubt be accepted as entirely trustworthy. But, even in such cases, the bare results were too often quoted without a sufficient explanation of the conditions. For instance, the water raised might have been deduced from the gross displacement of the plungers, or an allowance might have been made for slip, or, in rare instances, the discharge might have been actually measured. Without a common basis in this respect, comparison was impossible. Further, there prevailed in America the custom of surrounding the main engine with satellites in the shape of independent air-pumps and feed pumps, thus relieving the main engine of duties commonly discharged by it in this country. In these days of superheat too, it was very necessary that it should be stated, when a steam consumption was given, whether superheat had been used, and to what extent.

The remarks made with reference to the relative flexibility in use against varying loads of single, compound, and triple expansion engines were directed to power units working with a constant steam pressure, and were of course correct. The writer had, however, in

the case of large pumping engines, found by experience the immense advantage of varying the steam pressure supplied to engines which had at times to work against heads above or below those for which the engines were originally designed. By this means the actual usefulness of an engine might be greatly increased.

Mr. William Schönheyder wrote that he would be glad to know what arrangements were made for working the suction under pressure (page 22, par. 5)—was the suction-water first pumped up into an overhead tank, say by a centrifugal, as was the general practice at hydraulic stations in this country, or was the pump placed deep down in a well, or how? On page 24 it was stated that a pump was pumping against "a closed valve"; this should either be "a weighted valve" or "a partly closed valve."

Would the author kindly supplement his Paper with an exact sketch of one of the 3½-inch spring-loaded valves mentioned in page 25, line 7, stating the number in use, the size of pump with length of stroke and number of revolutions per minute—of course of a satisfactory working engine.

Mr. Barr wrote that in several of the engines (if not all of them) described in the Paper, the air and feed pumps were on the main engine, so that the steam used for these auxiliaries was included in the duty given for the engine. So far as the author recollected, Minneapolis was the only place where superheated steam was used.

In reply to Mr. Schönheyder, the suction-water flowed into the pump under a head of, in some cases, as much as 50 lbs. per square inch, and was connected direct to the pump suction main. Thus, if the engine was pumping against a head of, say, 150 lbs. per square inch, the real head on the pumps was only 100 lbs. The centrifugal pump, referred to on page 24, was pumping against a closed valve when the author saw it at work. The pressure on the discharge side of the pump was 100 lbs. per square inch, and connection had not been made with the city mains. The author sent a sketch of pump valve, Fig. 16 (page 56) as nearly as he could remember it. He did not know how many of these were

(Mr. Barr.)

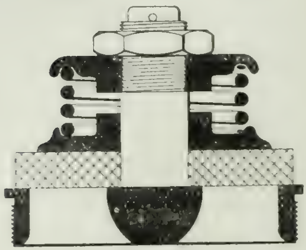
employed in the Cincinnati engines, but on page 29 he gave the number used in the St. Louis engines, which were about the same power as those at Cincinnati. The diameter of the plungers and the length of stroke were also given.

Fig. 16.

$3\frac{1}{2}$-in. diam.

Suction and Delivery Valve.

Cincinnati Water Works.



SOME FEATURES IN THE DESIGN AND CONSTRUCTION OF AMERICAN PLANING MACHINES.

By Mr. ARCHIBALD KENRICK, Jun., *Associate Member*, of Tunbridge Wells.

Between this country and America there is a difference of conditions, which manifests itself all through the design and construction of a machine, from the general features down to the smallest detail. America is a huge developing country, with a large, ever-increasing and sure market for her goods; hence people are readier to specialise in one article than they are here. Likewise there is a greater demand for labour, and it commands a very high price. Therefore every effort is made to minimise labour. To effect this, in the case of machine tools, they must be made as far as possible automatically, which results in the manufacture of standard patterns. Buyers cannot afford to have their whims and caprices attended to; they must buy what they can get manufactured. Further, the tool in its turn when in use must take a minimum of human time in manipulation, and must not produce bad work, which wastes labour to rectify. Minimum of attention seems to come before maximum of output, as is seen when one casually glances at half-a-dozen automatic lathes under one operative. The lathes are working well within their power, evidently because they cannot be closely watched and nursed; whereas full value is got out of the man. Thus there are many instances of American firms specialising in one tool and adhering to standard patterns even in this. Great excellence of quality and refinement of detail is the result. But this state of things would no doubt tend to the ossification of ideas,

if not more than counterbalanced by the spirit of enterprise bred in a great developing nation and enhanced by the exhilarating effect of their climate.

Several works where planing machines are made were visited by the author, and machines were seen in operation in many places. A Cincinnati firm afforded the best example of a factory where nothing but planers, and these of the most ordinary and useful sizes, were made. This firm was also the readiest in giving information. The machines seen in America were made of distinctly thin metal throughout; and the outside appearance was everything that could be desired. Better shapes can be given to castings if their models are kept standard and are not altered. In one works, to economise shop room, only the cross-slides, boxes, gearing, feed motion and other light parts were made to stock. The heavier parts were cast, and quickly got up when an order was received.

Beds mostly have the usual V's, planed considerably more acute than 90°, and are generally lubricated with rollers. The V has the advantage of requiring no setting-up slips; while flat ways are easier to lubricate, to get true on foundations and to keep true afterwards; all especially useful for long machines. Flat ways also are better for heavy work. In the larger sizes many new machines were made with a guiding V on one side and a flat on the other.

Tables are furnished with longitudinal T-grooves and dog-holes at intervals. The Cincinnati firm find it better to drill these holes to jig instead of casting the usual square holes. This saves trouble with core prints, and gives the table a better surface to machine.

The cross-slides have a rectangular guide at the top with some sort of slip, and a V guide near the bottom, Fig. 1. American machines do not plane on the return stroke, and this arrangement forms a first-class support for the cutting stroke.

The drive is done in many different ways. The most usual one is by rack and pinion and spur gearing throughout up to the pulleys. At Cincinnati the pinion was of an unusually large diameter, having about thirty teeth. This was done to give a steady motion to the table. The pinion was, of course, well keyed to a short stout shaft.

At the end of the stroke, the table knockers, transmitting motion through levers and links, strike the belts. There are two of these, one for cutting and one for running back. Narrow single belts at very high velocities are used, to offer the least possible resistance to striking. The width of belt for a 3-feet wide machine is about $1\frac{1}{4}$ inch. For larger machines, spiral pinion and rack to drive the table is used extensively. The angle between the spiral shaft and

FIG. 1.—*Section of Cross-Slide carrying Tool-Box Saddle.*

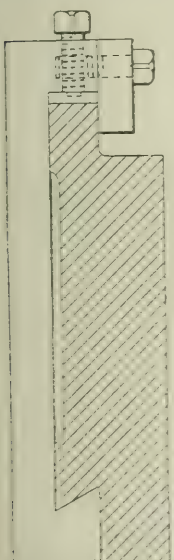
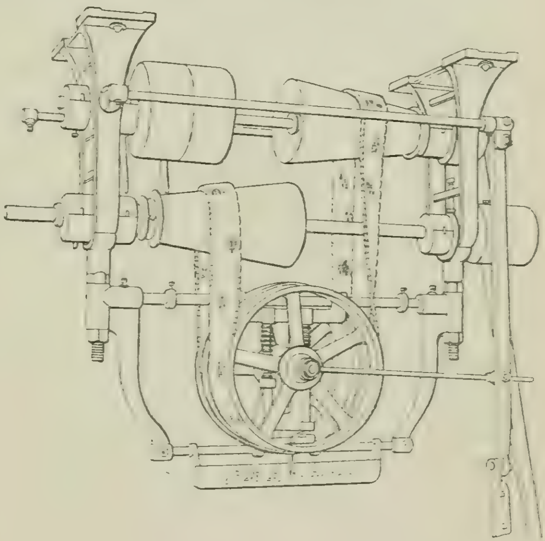


FIG. 2. *Speed-changing Device.*



the rack is not 45° but considerably more acute, say 40° or less. At Cincinnati the shaft bearing and pinion oil-bath are made in a casting separate from the bed, for convenience of manufacture. Thereby they avoided having to bore the bed on the skew. The rack-teeth were milled, and the spiral was milled in the lathe. Both were made of cast-iron. The pulley-shaft geared up to the spiral pinion shaft with bevel wheels.

The pulley-shaft and countershaft were made exceedingly heavy and of best tool steel, so as to run very steadily, to bear evenly in the long cast-iron bearings (which were not made to swivel), and to wear for a very long time. Pulleys keyed on to such shafts would never come loose with the roughest wear. The countershaft was run in cast-iron long bushes, which were held in position in their hangers by running in babbitt in the annular space between the bush and the hanger. This was done when everything was in alignment.

All spur-gear was milled and all bevel-gear planed, and every pair of wheels was run at the correct centres and angle in a special machine before assembling. By these precautions very smooth running was obtained. This was well shown by a glass of water placed on a moving table in which no ripple was visible, except at reversal.

Jigs are used for almost everything. The table and bed V's are each planed to jigs, and the result is so good that all that is necessary to finish is to scrape off the mark of tool. This does not apply to the cross-slide, which has to be got up more carefully. The bolt-holes to attach the arms to the bed and cross-head were drilled to templet; and the parts came together without a hitch. They stop only at drilling steady-pin holes to jig. The following is a remarkable example of the precision of their work :—

The pulley-shaft had to fit its bearings and several fast-and-loose pulleys without any letting up afterwards. On its running surfaces two spiral oil-grooves were cut in the lathe. These spirals were of opposite hands, and intersected at a certain point. An oil-hole was drilled in the bearings, and when the shaft was inserted the oil-hole always came opposite the desired point, which was the intersection of the two oil-grooves.

Some firms employ friction clutches in the drive instead of belt striking gear, especially for the larger machines. These are easier to throw than belts, and they give rise to less variation in the length of stroke. Still better results in this direction were obtained by a new device seen on an 8-foot square machine, where at the points of reversal a cock opens admitting compressed air which blows the clutch across from one gear to the other.

Friction-clutch machines are motor-driven very conveniently without a countershaft. Two other forms of drive were seen at Cleveland in which electricity played a prominent part in reversing. In one, an electro-magnetic clutch was pulled alternately to the direct and to the reverse gear. In the other, the knockers threw a switch which reversed the field magnetism and so the rotation of the motor, and also gave it a quick return speed. It was done by a new type of Westinghouse motor which was attached to one of their existing machines. This seems to be the most direct way of all.

In American planers a very high rate of speed is obtained on the quick run-back stroke, being about four or five times the cutting speed. But the cutting speed is nothing extraordinary, and the quick-cutting steels do not seem to have asserted themselves yet. When they do, they will raise the speed of the cutting stroke, but not that of the return, which is probably already as high as is feasible. The next step may be to run the machine at a constant high speed both strokes, and cut with double-cutting tool-holders. At present they do not seem to press the output of machines to their utmost limit, but, as in the case of the automatic lathes mentioned above, so with all but the largest planing machines, they prefer to have many, taking little attention, under one man. Nor are broad feeds supplied for quick finishing cuts. The simple pawl feed from a jumping rack at the side of the arm was used everywhere, and the momentum of the moving parts at reversal supplied the power to move the jumping rod. In several works where they wished to increase the output of existing machines, planers were run from a Reeve's variable speed countershaft, which gave great satisfaction. Where a few machines have to do a large variety of work differing in hardness and class, it is clearly an advantage to be able to vary the cutting speed. On hard stuff or in a cramped position it is desirable to run much slower than usual.

Another new speed-changing device was shown at the St. Louis Exhibition. This was based on the familiar apparatus consisting of two cast-iron taper cones geared together by a belt with forks to locate the belt and keep it from climbing. For the forks were substituted two guide-pulleys as shown in Fig. 2 (page 59). This arrangement

allows a good length of belt, and obviates the continual friction on the forks. The belt was a link belt (though it might have been a common belt), and was kept tight by springs acting on the guide pulleys. It worked well and had great driving power. A two-speed countershaft or a pair of stepped cones would no doubt serve nearly as well for this purpose.

The cross-slide is commonly raised by a chain and wheel at the end of a horizontal shaft in the crosshead. In the larger machines a pulley is placed on the shaft, and in motor-driven machines a separate motor is used. In some very large machines motors were used for moving all the boxes as well.

The Paper is illustrated by 2 Figs. in the letterpress.

Discussion on 20th January 1905.

The PRESIDENT thought the members would agree with him that the Paper showed a very intimate knowledge of the details of planing machines, and an intelligent observation of the methods adopted, both in the design and manufacture of machines, in the States. He asked the members to convey by their applause their thanks to Mr. Kenrick for his Paper.

The resolution of thanks was carried by acclamation.

Mr. L. PENDRED said he hoped there were present some makers of machine-tools—particularly planers—who would direct their attention to the details of these machines. The author had raised several interesting points in his Paper, and had given an excellent brief review of American practice. He thought, however, that British machine-tool makers could show that as good work was designed in this country as any that had been seen in America. He would like to say a word or two about the reversing gears to which Mr. Kenrick had called attention. Three such gears had been

mentioned; all were interesting as attempts to solve one of the most difficult problems presented to the designer of planing machines —that of the reversing motion. He did not regard any of these gears as a final solution of the problem. They consisted of a pneumatic device, a magnetic device, and an electric gear. The first was open to the objection that it added to the complication of the machine, and involved the use of compressed air, which was to be obtained either from the shop main or from the machine itself. Moreover, although it worked well, it was no better than a mechanical device, and by introducing more parts in inaccessible places it added to the cost of purchase and upkeep. The same objection of complication attached to the magnetic reverse, and certainly there was greater liability to breakdown. Judging from the outside view, there was the defect that a heavy disc rotating at a high speed had to be reversed at each change of direction, and there was no more effectual way of wasting power in a planing machine than by reversing a rapidly-rotating and heavy body. The electric reversing-gear was an exceedingly pretty thing, and worked beautifully, but the same objection again applied. When it was remembered that the armature would possibly weigh about 300 lbs., and run at 700 turns per minute, the fact that much power was involved in starting and stopping it was not difficult to appreciate. The reversing gear was very neat, but it introduced a number of moving and wearing parts, and therefore could hardly be called simple. In one gear, with which the speaker was allowed to make several rough tests, there were two panels, each panel having four switches, each worked by a solenoid, besides the reversing-switch itself. The electric action was, the speaker understood, as follows: After switching on the current, the motor rapidly attained a certain speed, generating a back electromotive force; this was at length high enough to energise the first solenoid, which threw in the first switch, cutting out the resistance and allowing the speed to ascend until the next switch was similarly drawn in. The action was very rapid, and it seemed quite impossible to upset the action by moving the reversing switch rapidly backwards and forwards. In all these gears, however, it would not be right to assume that, because they worked well, they

(Mr. L. Pendred.)

were therefore satisfactory; cost, wear, up-keep, and experience involved in their use, were points which had to be considered.

Mr. Kenrick had referred to a change-speed gear, and change-speed gears, as a whole, enforced this very point. At the Westinghouse Works Mr. Christopher James and the speaker were allowed to read a confidential report on twenty-five change-speed gears, based on tests made by the company's engineers. Some of the machines had reputations, others had "pasts," but not one out of the twenty-five was considered able to fulfil the not very onerous conditions laid down, and most of them failed because of a high rate of wear and tear. Some wore out their belts, and some wore out the pins or the teeth. Opposing cone gears were always hard on their belts unless they were worked far below their capacity. Some gears made too much noise, and some failed to have an efficiency that would bring them into the market at all. Finally, the speaker thought there was still considerable scope for invention in the planing machine, particularly in the direction of the variable-speed gear, and a really simple and effective reverse.

Mr. Daniel Adamson said that, although he had not given the subject the attention the last speaker had, he thought Mr. Pendred had omitted to observe one of the most important points in connection with the reversing of a planing machine, namely, the element of time. The action of the switches, which was well illustrated by Mr. Pendred rapping upon the table, made the electrical arrangement very slow. The pneumatic clutch was very good, but while in America he was given to understand that if used on short strokes it gave trouble by over-heating.

Discussion on 17th February 1905.

Mr. C. Liddell Simpson said that a good many of the members would remember having seen a planing machine called the Gray.

It was driven by very fast-running belts, had a very quick return, and ran very nicely indeed. The same ideas were being embodied on planing machines now being built by a great many makers in this country. The old form of planer driven by a worm gear, which was designed by Messrs. William Sellers and Co. of Philadelphia, he thought should receive more attention than it had done. It ran very well, and used to be made by Messrs. Sharp, Stewart, of Manchester. Having now come to such high-speed tools, he thought that a form of planer driven with a worm with very fast-running gear would be worth the attention of the tool makers.

Mr. KENRICK, replying, said that there had been but little criticism on his Paper. Mr. Simpson had said that he thought the Sellers geared-machine ought to have more attention paid to it. In America the Gray Co. made that and their own machine, and, of course, Messrs. William Sellers and Co. made the Sellers geared-machine; but there was at least one firm in England besides the Manchester firm making this type, namely, Messrs. Joshua Buckton and Co. of Leeds, who had made it for a long time. Their spiral pinions being cut in steel and case-hardened were very suitable for hard work and the high speeds Mr. Simpson spoke of. He thought the criticisms of Mr. Pendred and Mr. Daniel Adamson about the various new methods of reversing were on the whole very well founded; but with regard to the pneumatic reverse, it had to be remembered that if it introduced further complications, it at the same time displaced a train of ramshackle links and levers, and was certainly a neat way of actuating a friction-clutch, which in the author's opinion was the best way of reversing a large high-speed planer. This opinion was founded on the following considerations. Kinetic energy accumulated and had to be dissipated and renewed, or else given and taken from some sort of buffer at the end of each stroke. In either case the more the energy accumulated, the longer would be the time of reversal or the greater the shock. Kinetic energy accumulated mainly in two places—the table with the work, by virtue of its great mass; and the pulley-shaft, by virtue of its high velocity. In a belt-reversed machine, about as much energy

accumulated in the fast pulley rim as in the reciprocating mass—it might be more or it might be less. The surfaces of friction-clutches did not require to run at anything like the velocity that light, easily-struck belts required to transmit the same power. Therefore, with friction clutches, there was little more than the inertia of the table to overcome, which was already partly balanced by the friction of the ways. Hence, more heat would be produced at the striking of a belt than at the engagement of a friction-clutch; but in the latter case good ventilation or other means of cooling should be provided to prevent overheating on short strokes.

Communication.

Mr. E. KILBURN SCOTT wrote that he was glad the author had referred to the very neat speed-changing device by cones and guide pulleys, which dispensed with belt forks.

In electric motor driving work there was a sort of craze at the present time to carry out all speed changing by regulation of electric motor speeds, with the result that larger and more expensive motors and controllers were necessary. This method also generally entailed greater tendency to sparking, and very often the power was reduced by reason of reduced speed just at the very moment when it was most required. In a 3-phase motor there was difficulty in changing speed, and this was often put forward as a reason why the direct current motor should always be used in motor installations. As a matter of fact, however, if the millwrighting part of the installation was properly taken in hand there was no disadvantage at all. This he thought was conclusively shown by the fact that two of the largest electrical factories in the world, the British Westinghouse Works at Trafford Park, Manchester, and the works of the Allgemeine Elektricitäts Gesellschaft in Berlin were equipped throughout with 3-phase motors. The use of such a speed-changing device as the author referred to, with cones and guide

pulleys, went far to obviate the necessity of changing motor speeds. Electrical engineers were lacking as a rule in millwrighting knowledge, and frequently went to all sorts of trouble and expense to obviate a little belting or a well known and tried mechanical device.

Mr. Kenrick, in reply to Mr. Kilburn Scott, wrote that he had been under the impression that those who used electric power and drove machines with separate motors would prefer to vary the motor speed direct, and not use an intermediate gear. He believed that the defects of the gear illustrated were low efficiency and small speed range, only $2\frac{1}{2}$ to 1. For planers he deprecated the use of any such gear, and preferred the system of having two or three changes of toothed gears corresponding with the two or three classes of material to be cut.

ENGINES AT THE POWER-STATIONS, AND AT THE ST. LOUIS EXHIBITION.

By Mr. ALFRED SAXON, *Member*, of Manchester.

The author of this Paper, before proceeding to the Joint Meeting in Chicago, took the opportunity of visiting two of the large power-stations in New York, namely, the Manhattan Division Power-House in 74th Street, and the Interborough Rapid Transit Power-House, Figs. 1 and 2 (pages 72 and 73) situated between 58th and 59th Streets. At the former station the plant was seen in full operation, but the latter station was not quite completed. Both stations are equipped with the Manhattan type of combined twin vertical and horizontal compound engine, Fig. 3 (page 74), with a rated power of 7,500 I.H.P., but capable of developing 50 per cent. overload when required. As a comparison of the engines in the two stations may be of interest, a summary of the principal sizes is given in the following Table 1 (page 70).

The guarantees under which the main engines for the Rapid Transit Co. are being furnished, and which will govern their acceptance by the purchaser, are in substance as follows: (1st) The engine will be capable of operating continuously when indicating 11,000 horse-power under the conditions of steam-pressure and speed mentioned, and a 26-inch vacuum, without abnormal wear, jar, noise or other objectionable results. (2nd) It will be suitably proportioned to withstand in a serviceable manner all sudden fluctuations of load, as are usual and incidental to the generation of electrical energy for railway purposes. (3rd) It will be capable of operating with an atmospheric exhaust with 2 lbs. back-pressure at

TABLE 1.

	Manhattan. 74th Street.	Rapid Transit. 58th Street.
Diameter of high-pressure cylinders . . inches	44	42
,, ,, low ,, ,, . . . ,,	88	86
Ratio of cylinders	4 to 1	4·19 to 1
Stroke . . . . inches	60	60
Speed . . . . revs. per min.	75	75
Steam pressure at throttle . . . . lbs.	150	175
Indicated horse-power at best efficiency . . .	7500	7500
Diameter of low-pressure piston-rods . . inches	8	10
,, ,, high ,, ,, ,, . . . ,,	8	10
,, ,, crank-pin . . . . . ,,	18	20
Length of crank-pin . . . . . . ,,	18	18
Type of low-pressure valves	Double ported Corliss	Single ported Corliss
,, ,, high ,, ,, ...	Corliss	Poppet Type
Diameter of shaft in journals . . . inches	34	34
Length of journals . . . . . . ,,	60	60
Diameter of shaft in hub of revolving element . ,,	$37\frac{1}{16}$	$37\frac{1}{16}$

the low-pressure cylinders, and when so operating will fulfil all the operating requirements, except as to economy and capacity. (4th) It will be proportioned so that, when occasion shall require, it can be operated with a steam-pressure at the throttles of 200 lbs. above atmospheric-pressure, under the mentioned conditions of the speed and vacuum. (5th) It will be proportioned so that it can be operated with steam-pressure at the throttle of 200 lbs. above atmospheric-pressure, under the before-mentioned conditions as to speed when exhausting in the atmosphere. (6th) The engine will operate

successfully with a steam-pressure at the throttle of 175 lbs. above atmosphere, should the temperature of the steam be maintained at the throttle at from 450° to 500° F. (7th) It will not require more than $12\frac{1}{4}$ lbs. of dry steam per indicated horse-power per hour when indicating 7,500 H.P. at 75 revolutions per minute, with the vacuum of 26 inches at the low-pressure cylinders, with a steam-pressure at the throttle of 175 lbs. and with saturated steam at the normal temperature due to its pressure. The guarantee includes all of the steam used by the engine or by the jackets or reheater.

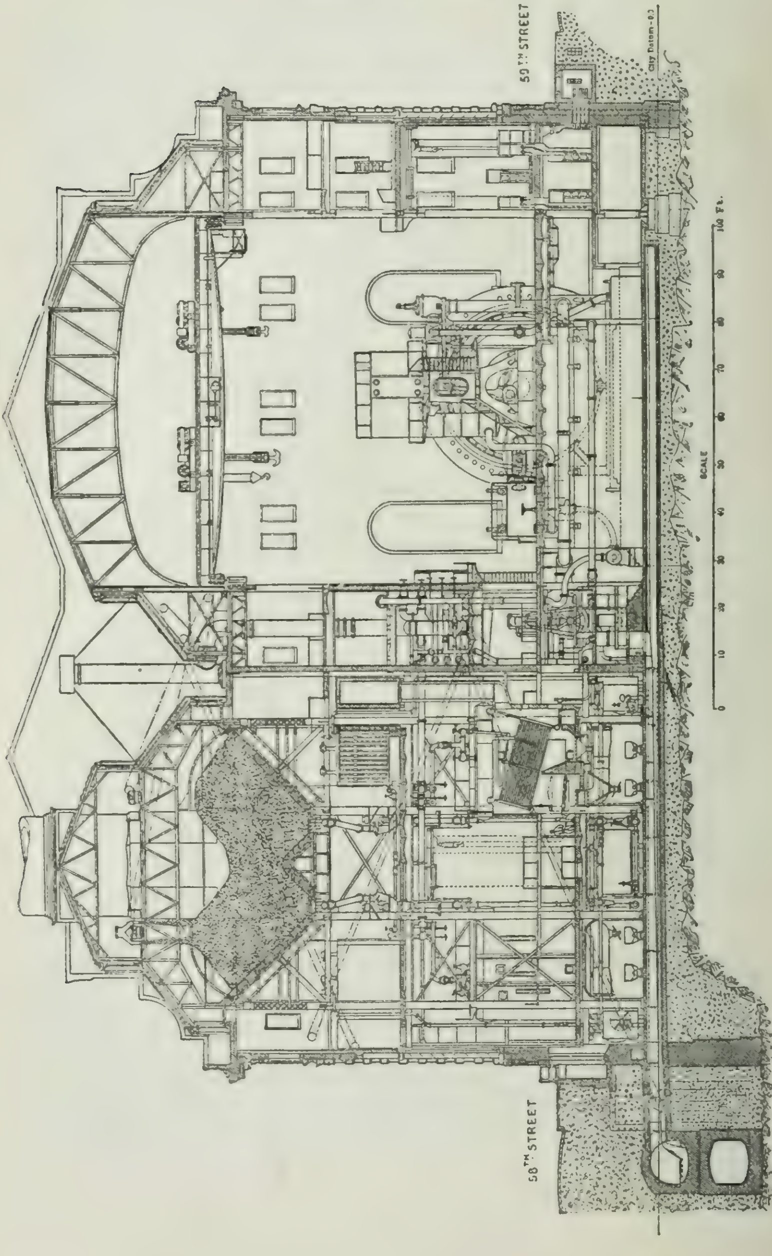
The weight of the revolving field is about 35,000 lbs., which gives a flywheel effect of about 350,000 lbs. at a radius of gyration of 11 feet, and with this flywheel inertia the engine is designed so that at any point on the revolving element shall not, in operation, lag behind nor forge ahead of the position that it would have if the speed were absolutely uniform, by an amount greater than one-eighth of a natural degree.

In regard to the chances of increased wear in the bearings due to the all-round character of the pressures on the crank-pin, the author does not consider that there are chances of increased wear, owing to the fact that there are two separate connecting-rods connected to the one pin, one being connected to the horizontal, and the other to the vertical cylinder; and while the pressure on the pin is fairly constant, due to the four separate steaming impulses from the two cylinders in one revolution, still the pressure on each rod is variable, allowing the lubricant the same opportunity of keeping the pin cool and preventing wear, as in the case of any other double-acting type of engine. Provision in this case has however been made for dealing with wear, by the adoption of adjustable straps for the crank-pin end of connecting-rods, instead of the marine style of construction.

The power-house (11th Avenue and 58th Street) of the Interborough Rapid Transit Co., Figs. 1 and 2 (pages 72 and 73), is designed for a plant of a capacity of more than 130,000 horse-power, and will, when completed, be the largest power plant of the kind in the world. The plant is divided into six sections; five of these sections will be completed immediately, and will include a turbine section. The equipment of each comprises two main engines with barometric

Power-House of Interborough Rapid Transit Railroad, New York.

FIG. 1.—*Cross Section.*



Power-House of Interborough Rapid Transit Railroad, New York.

FIG. 2.—*Plan of one of the six Sections.*

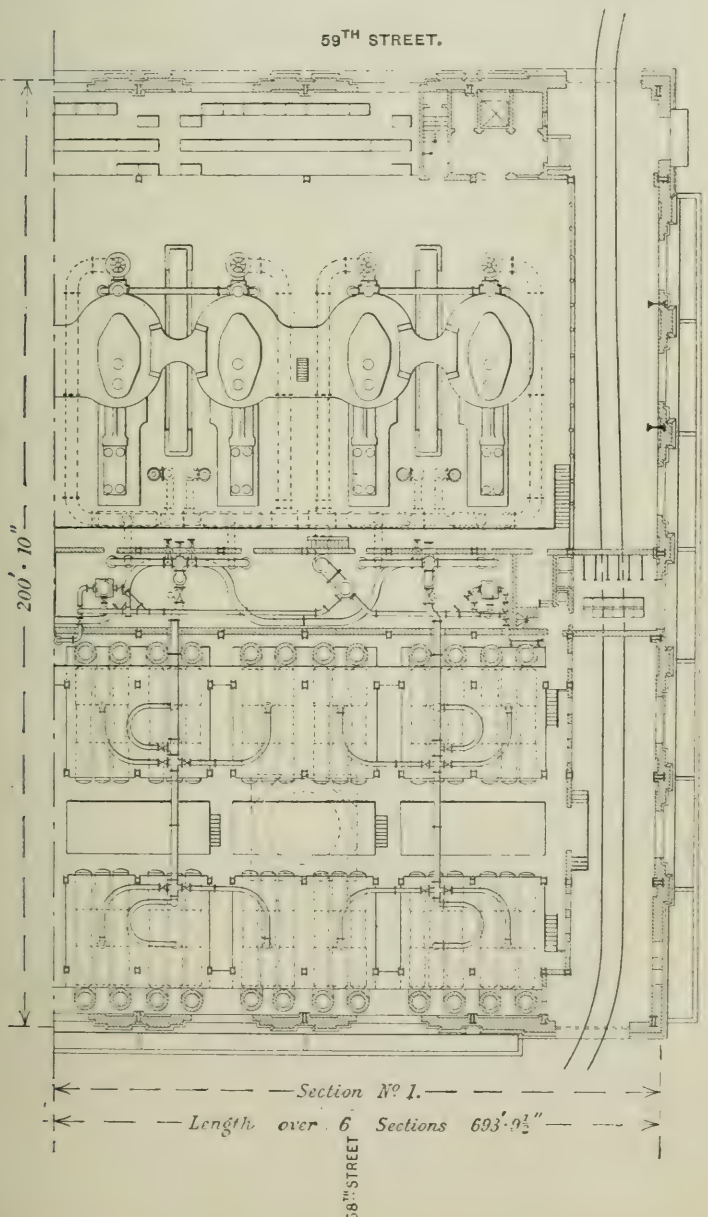
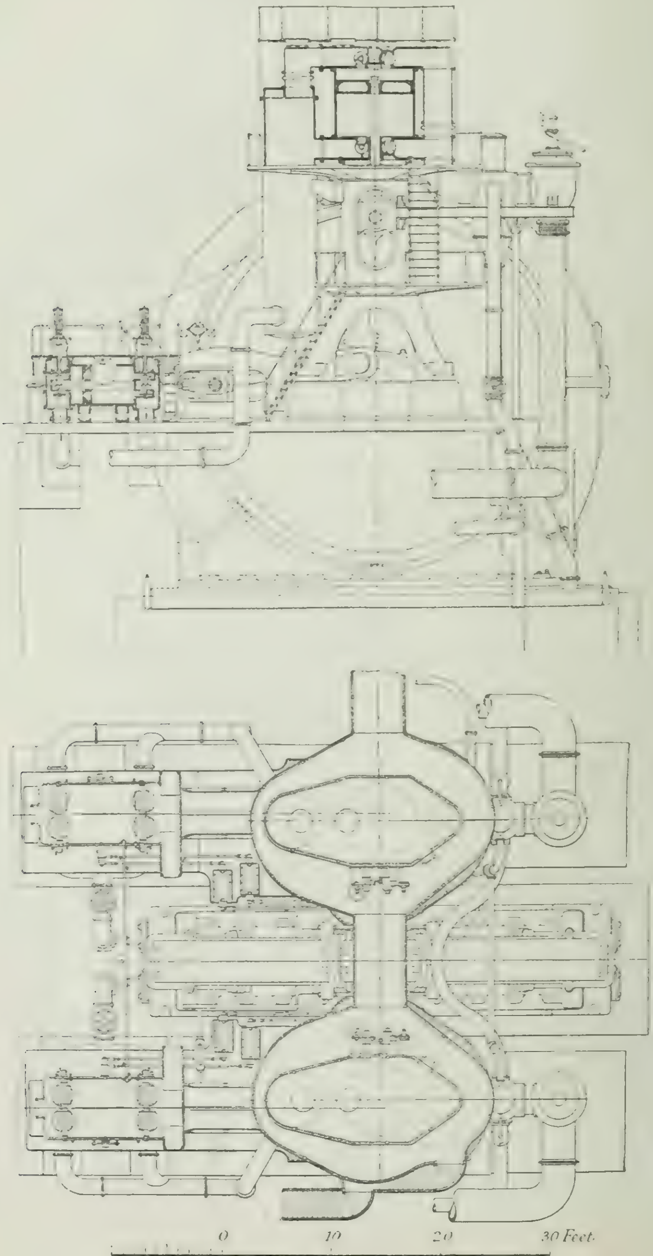


FIG. 3.—7,500 *I.H.P. Combined Twin Vertical and Horizontal Compound Engine, Interborough Rapid Transit Railroad, New York.*



condenser sets, two circulating water-pumps, two boiler feed-pumps, and one stack, and provision is made for the installation of economisers. The turbine section is designed to accommodate four 1,250 kilowatt steam-turbines and one large steam-engine unit similar to the units in the other sections. This section also is fitted with the requisite auxiliary engines, pumps, and heaters, &c. The boilers are of the Babcock and Wilcox type, having 6,000 square feet of heating surface each, and are built to carry a working pressure of from 175 lbs. to 200 lbs. The majority of the boilers are stoked by hand, but in some cases mechanical stokers have been installed. Also some of the boilers are equipped with superheaters, the superheated steam being intended to be used largely for the turbine section.

The Engines at the Exhibition.—At the time of the visit to the Exhibition, the exhibits in the Machinery Hall were not in a finished condition, but the most important of the steam-engine exhibits were completed and could be seen under varying conditions of load. The most extensive and imposing exhibit was the group of four cross compound vertical engines by Westinghouse, Church Kerr and Co., made at the Pittsburg Works, connected to alternating current generators of 2,000 kilowatts. The high-pressure cylinders were 38 inches diameter, and the low-pressure cylinders 76 inches diameter, the stroke being 4 feet 6 inches, and the revolutions 83. These engines were not of unusual or extraordinary size for power-station work; they were rated at 3,200 I.H.P., giving a total for the complete installation of 12,800 I.H.P. It may be noted that these engines were connected to barometric condensers.

Next in order of size, but surpassing it in interest, novelty, design, and mechanical skill, and in the attention it attracted, was that of the Allis-Chalmers Co., who exhibited a combined horizontal and vertical 5,000 I.H.P. compound engine, Manhattan type, Fig. 4, Plate 2. They have named it the "Big Reliable," and it is undoubtedly the largest two-cylinder engine that has ever been exhibited; in fact, the makers claim that it is the largest two-cylinder engine ever built. It is capable of developing 8,000

I.H.P., and is connected to a Bullock generator of 3,500 kilowatts, 6,600 volts, twenty-five cycles, three phase. It is a single-crank engine, and, owing to the placing of the cylinders, makes four impulses per revolution; the crankshaft is not prepared for the addition of another unit, but, if this size of engine were constructed of the twin type, 10,000 H.P. could be developed from one unit, or a maximum load of 16,000 H.P. The high-pressure cylinder is horizontal, 44 inches diameter, and the low-pressure cylinder is vertical, 94 inches diameter, the cylinder ratics being $4\frac{1}{2}$ to 1, stroke 60 inches, steam pressure 150 lbs., speed 75 revolutions per minute. The fly-wheel is 25 feet diameter, and weighs 300,000 lbs. The shaft is hollow, 37 inches diameter, weighing 61,000 lbs.; the weight of the crank, which is fan-tail type, is 32,000 lbs., and the weight of the revolving parts is given at 514,000 lbs., the total weight of the engine and generator being 720 tons. The height of the engine above foundation is 39 feet 2 inches, and the length over all 39 feet. This engine and generator supplies current for 120,000 electric lamps for the decorative lighting of the World s Fair, and current for operating the electric cars of the St. Louis Transit Co. This engine is also connected to a barometric condensing plant.

Next in size and importance is the Hamilton Corliss Engine Co.'s cross compound vertical engine connected to a 1,500 k.w. generator; the engine is rated at 2,250 I.H.P., and works at 83 revolutions per minute, the same speed as the Westinghouse engines. It is designed on the Allis vertical model, and is connected to a surface-condenser.

The Brown Corliss Engine Co. exhibit two cross compound vertical engines connected with generators of 800 H.P. and 500 H.P. respectively. These engines bear evidence of the influence of the Allis design being a predominant factor in American engineering.

Still dealing with the vertical type of engine, reference may be made to the Willans Engine Co.'s triple-expansion engine of 1,000 I.H.P. It was arranged to run a speed of 277 revolutions, and was finished in the well-known style of the English firm. The Delaunay Belleville Co. were installing, at the time of the author's visit, one of their type of high-speed engines, but it was not quite completed.

The horizontal type of engine was in evidence at the Exhibition, although this type has not been adopted for the generation of electricity in the large power-stations, with the exception of the Allis plan of utilizing it in combination with the vertical type. Some good examples were exhibited of engines of moderate size, including a tandem-compound of excellent finish and workmanship of 1,000 I.H.P., designed to run at 94 revolutions per minute with a 50-inch stroke, exhibited by the Belfort Société Alsaciennes of Mulhouse. Other types of horizontal engines were exhibited by the Lane and Bodley Co., and the Greenwald Co., both of Cincinnati, both being of the cross-compound type. These engines, along with one exhibited by the Murray Iron Works, which was a single-cylinder Corliss engine, and a tandem-compound Fleming engine 4-valve, made by the Harrisburg Engine Co., all of about 1,000 H.P. each, furnished the current for the Intramural Railway Service of the World's Fair. The Buckeye Engine Co. also exhibited a cross-compound horizontal engine of 1,000 H.P. The engines were located principally in the Western Section of the Machinery Hall, and probably aggregated about 40,000 I.H.P. as a maximum.

In concluding this brief Paper, the author would like to add that the Engineering Section of the St. Louis Exhibition proved to be rather disappointing after the visits he had made to the large power-stations in New York. These stations were constructed on an impressive scale, and gave a far better idea than the Exhibition of the ability and resources of American engineering to deal with the great power problems with which they are confronted, especially in such a city as New York. Without expressing any opinion as to the suitability and merits of the steam-turbine versus the steam-engine for power-station work, he might say that the evolution in the development of the steam-engine for this purpose has resulted in the introduction of a class of engine which is a compromise between the two well-known types, namely, the combined horizontal and vertical compound engine known as the Manhattan type, because of its being first introduced in the Manhattan power-station. This is a type which meets with his entire approval, for space occupied, for evenness

of turning effort, for accessibility for overhauling and repairs, and for the placing of the cylinders to prevent undue wear; these and other advantages combined make this type unequalled for this special purpose. The application of the barometric type of condensers at the stations visited, and at the Exhibition, was a proof that this condenser is giving excellent results. The engineering section of the Exhibition also suffered in the fact that while it was fairly representative of American engineering, it would not compare in interest and educational value with the Paris Exhibition of 1900, which was much more extensive and altogether more representative of the general engineering skill and practice of the world. With regard to the finish of the engine exhibits, they did not quite come up to the standard of European exhibitions.

The Paper is illustrated by Fig. 4, Plate 2, and 3 Figs. in the letterpress.

Discussion on 20th January 1905.

The PRESIDENT said the members had already by their applause conveyed their thanks and appreciation to the author for his very valuable Paper.

The four Papers which were down for discussion had all been read, but when the members received their Proceedings of the Meeting they would find two more contributions from members who visited America, one by Mr. Stanley Bott upon "American Woodworking Machinery" (page 89), and another by Mr. Charles Wicksteed upon American Methods generally (page 97).

Mr. MARK ROBINSON, Member of Council, did not think that anyone interested in steam-engines would trust himself at the present stage of the proceedings to start a discussion, or they might never reach the next Paper, but he would like to ask the author one or two questions, for reply later. In the first place, Mr. Saxon used the

expression "An eighth of a natural degree." Were the members to understand by that, an eighth part of $\frac{1}{360}$th of a circle, or did he refer to what electricians called an electrical degree, namely $\frac{1}{360}$th of the distance between two poles of the same kind? In considering the variation of torque in an engine, one required to know the number of poles before saying whether a certain variation, if expressed in "natural degrees," was good enough, say, for running alternators in parallel.

He also wished to ask the author his opinion on the advisability of providing for a 50 per cent. overload. The mere possibility of a 50 per cent. overload appeared to imply an unduly early cut-off in normal working—for a compound engine.

He would also like to ask the author what impression he formed as to the probable wear of the main bearings in the "Manhattan" type of engine. In the bearings described it was neither a question of a plain pull up and down, as in an ordinary vertical engine, or of a similar plain pull horizontally; in the "Manhattan" type both bearings were combined in one set of brasses. If the author would tell them his own personal opinion upon that question he thought it might interest many of the members.

Mr. VAUGHAN PENDRED asked the author whether engineers in America claimed the combination of a vertical and a horizontal cylinder as an invention. His own impression was that it originated with McNaught many years ago in this country, when spinning mill engines were often improved and compounded; and he remembered seeing an engine of the type thirty years ago in a steel works in Styria, where the horizontal and vertical engine were combined. He could not say offhand whether it was a compound engine or not, but there were two engines, one vertical and the other horizontal, driving a rolling-mill.

Mr. ALFRED SAXON thought it only fair to say at the outset that he had been asked to write the Paper not at the time of his visit to America, but on his return. On some of the points that had been referred to, he had been obliged to get information from the other

(Mr. Alfred Saxon.)
side of the Atlantic, and he had no information whatever with regard to Mr. Robinson's question as to the natural degree. He had simply inserted that in his Paper as part of the information which he was able to collect, some of which he had received direct from the engineer of the Interborough Transit Co.

With regard to the question of overload, it seemed to him, without going thoroughly into the matter, that the 50 per cent. overload claimed for the engine was an extreme overload. He had particulars in his possession of some engines in the Manchester Electricity Station, which were built at Wallsend, Newcastle-on-Tyne, and which he believed were the largest in Europe. They were triple-expansion engines. As Mr. Robinson had suggested, the greatest range of power that could be obtained, taking into account the generally accepted ratios of cylinders in compound and triple-expansion engines, in ordinary practice, was in a single-cylinder engine. With a single-cylinder condensing engine a greater percentage of overload could be obtained than with a compound engine; and a greater percentage of overload could be obtained from a compound than from a triple-expansion engine. The triple-expansion engines in the Manchester station were 6,000 I.H.P., and all that the makers had to undertake with reference to overload in those engines was that they would give 6,500 H.P. for two hours; so that in that case the makers practically only guaranteed to give 500 more H.P. for two hours—he supposed just at the peak of the load. He had not gone into the question of the proportions of cylinders and the point of cut-off at all in connection with the Paper, and he could not therefore answer Mr. Robinson's question very accurately; but the makers claimed to give the results, and the guarantees were stated in the Paper itself.

With regard to Mr. Pendred's question as to whether the makers claimed the engine as an invention or not, he scarcely thought they did. The combination was old in itself, and the system could not be described as "McNaughting." He believed the arrangement was first of all introduced in Lancashire in connection with what was called a "pusher"—a horizontal type of engine connected to a beam engine—which gave practically the same result as was obtained

with the combined plan of the Allis-Chalmers. But in making an engine of that type as a complete new engine, he would say that their claim to it being a new design in that respect would be a good one.

With regard to Mr. Robinson's question as to the crank-shaft bearings, he could not give the information asked for. The engines he saw were comparatively new engines. In the Manhattan power-station, which was at work, the engines were all in thoroughly good order. He would like to see them in a few years' time, and would then be able to say something about the wear. Had it developed in so short a time, he thought they probably would not have run the usual ten years of American service.

Discussion on 17*th February* 1905.

Mr. J. Hartley Wicksteed, Past-President, who had opened the discussion, desired to tell the members something interesting connected with Mr. Halpin. In America one found a sanguine and an optimistic race, who were generally much impressed with the superiority of their own products, and it was refreshing and a delight to him when he went to the McGill University at Montreal, the largest and best equipped mechanical laboratory in America—to find there a most elaborate experimental engine. It was one of the most wonderful engines he had ever seen, and it had been designed by Mr. Druitt Halpin. Although it was designed ten years ago, it was receiving the greatest praise, and was pronounced the best and most wonderful engine for experimental purposes the Americans had ever had. If Mr. Halpin were disposed to speak, he (Mr. Wicksteed) would like to hear him tell the Meeting about the different things that could be done with that engine, which was capable of being coupled up with all sorts of expansions and in every conceivable way in order to arrive at experimental results. Going away from England to a country that was really pre-eminent

(Mr. J. Hartley Wicksteed.)
in mechanical engineering and finding there that the engine they were most proud of was an engine designed by Mr. Druitt Halpin, and built in Lancashire, and holding its own now, ten years after it had been sent out, was a most delightful experience.

Mr. Druitt Halpin said the Montreal University engine * was made for the special purpose of experimenting in the mechanical laboratory. It was a vertical double tandem engine and was capable of a very great number of changes. The cranks could be placed at any angle to each other. There were four cylinders and they were all jacketed, but could work with or without jackets. Taking the cylinders as Nos. 1, 2, 3, and 4, No. 1 could be worked into No. 4 or into No. 3 or into No. 2, the whole sequence of the steam passing through the cylinders, and the engine could be worked condensing or non-condensing. One peculiarity the engine had was that the clearances could be varied. The normal clearance was 1·5 per cent. but that could be varied up to 48 per cent. This was done to see what the effect of clearance was through that very wide range. It was worked with a Froude brake at one end, and a water-brake with water trough inside the brake wheel at the other end, for absorbing the power generated. The great feature, however, was the capability of changing the sequence of the steam passing through the cylinder, the angles of the cranks, the clearances jacketing or non-jacketing, and condensing or non-condensing. It was by Messrs. Yates and Thom, of Blackburn, who had made a beautiful job of it in every way.

Mr. C. Liddell Simpson remarked that attention had been drawn to the design of engine where the high-pressure cylinder was placed horizontally and the low-pressure cylinder vertically, and he might mention that his firm had built several engines with somewhat similar arrangements. There was a very fine example to be seen of a triple-expansion engine built by Messrs. James Simpson and Co.,

* Proceedings 1905, Part 2, Plate 6, and Mr. Halpin's remarks on the First Steam-Engine Report.

driving the deep well-pumps at Barnet Water Works. The sizes of the cylinders were 17 inches high-pressure, 29 inches intermediate-pressure, and 45 inches low-pressure, with a 42-inch stroke, driving double sets of pumping gear. The low-pressure cylinder in this case was placed horizontally and the high and intermediate vertically, and this method of cylinder arrangement worked out very well and had given very good results. He was waiting with very great interest to see how the large electrical power-station now being erected at Lots Road, Chelsea, in connection with the electrification of the District Railway, where steam-turbines had been adopted, would compare with the type of engines described in this Paper as regards steam consumption and reliability in running.

Dr. Alex. B. W. Kennedy, Past-President, said he would like to mention a matter merely of history in reference to the large engines with horizontal and vertical cylinders, referred to by Mr. Saxon. The first large engines of that type of which he knew were marine engines made by Messrs. Palmers in 1869 for two ships of the Guion Company's line. They were compound engines, with 60-inch high-pressure vertical cylinders and 120-inch low-pressure horizontal (trunk) cylinders, the two working on to the same crank. The low-pressure cylinder had large Corliss valves, 18 inches diameter, worked by a wrist plate, but with rigid mechanical connections and no trip gear. As a leading draughtsman in Messrs. Palmer's drawing office at the time, he made the principal drawings for them, and he had no recollection that engines of that type, at any rate of any size, had been made at an earlier date.

Mr. James Molyneux said he had had experience of one of the engines referred to by Dr. Kennedy, having sailed in one of the ships, namely, s.s. "Wyoming." He spent twelve months on the ship, and the engines worked exceedingly well, and gave no trouble whatever. He thought the diagrams showed that they were very economical, and in the position in which they worked he believed that for their power they worked exceedingly smoothly. The cross-head pin of the low-pressure engine was fixed in the centre of a large circular

(Mr. James Molyneux.)

trunk, which passed and worked through both low-pressure cylinder covers. It might interest the members to know the method by which the low-pressure cross-head pin was "felt," namely, with a long syringe; a jet of water was played upon the gudgeon, and if any signs of steam were apparent it was considered to be getting warm. It could be imagined that when the engines were racing at sea at something like 100 to 150 revolutions per minute, great care was required to test the bearing, and that was the only process that could be used for "feeling" the cross-head gudgeon under those circumstances.

Mr. Saxon, in reply to the discussion, said that after considering the points involved in connection with the question as to the rated power of the Rapid Transit Co.'s engine by Mr. Mark Robinson, he thought the best plan was to give some theoretical diagrams showing the engines working under the conditions stated in the Paper and as rated by the maker, Fig. 5 (page 86). It was not necessary to go through the particulars, but it would be very interesting to make another comparison. There were four sets of engines being built in this country—in Lancashire—for the London County Council. These engines were rated at 5,000 I.H.P. working under normal load and capable, like the engines he had described, of working with 50 per cent. overload, Fig. 6 (page 87). The rating of the English engines was about $11\frac{1}{4}$ per cent. higher than the American engines. The case of the Allis-Chalmers Exhibition engine showed that the normal rating for 5,000 I.H.P. was higher than the Interborough engine, but did not differ much from the London County Council rating, whereas to develop 8,000 I.H.P. 60 per cent. overload was necessary, and required an average pressure of 50·72 lbs.; this rating was therefore higher than the London County Council rating (*see* Table 2 on page 85). It was interesting to find that those responsible for the design of the engines for the London County Council had made a departure by placing the low-pressure cylinders horizontal, and the high-pressure cylinders vertical, as they considered the best method was to work the steam downwards to the condenser.

TABLE 2.—*Calculations connected with Engines at the Power Stations and at the St. Louis Exhibition.*

Interborough Engines. Steam-pressure at the Throttle = 175 lbs. per square inch.	Normal Load. I.H.P.	Normal Load. Average pressure referred to L.P. Cyl.	50 per cent. Overload. I.H.P.	50 per cent. Overload. Average pressure referred to L.P. Cyl.
Each Engine rated at	3,750	28·59	5,625	42·88
Or, using the same average pressures as for the London County Council the rating would be about 11¼ per cent. more, or .	4,203	32·06	6,305	48·09
London County Council Engines.				
Boiler-pressure 180 lbs. per sq. in.				
Each Engine rated at	2,500	32·06	3,750	48·09
Or, using the same average pressures as for the Interborough, these engines would be rated at (about)	2,229	28·59	3,343	42·88

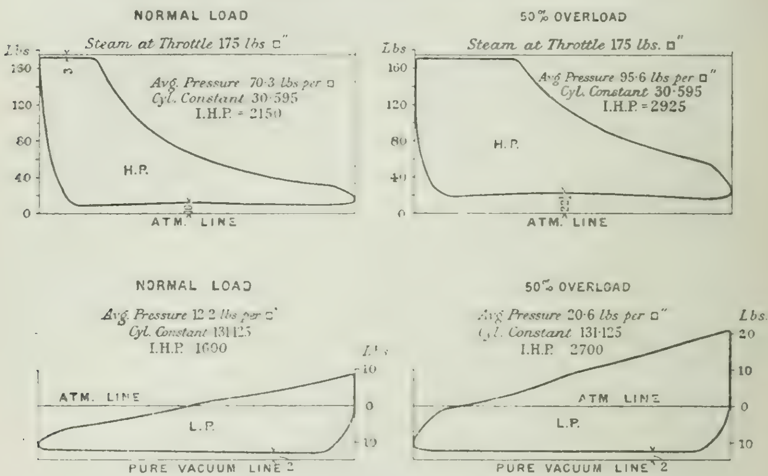
In comparison with the above, the particulars given below, of the Exhibition Engine, of the "Manhattan Type," made by the Allis-Chalmers Co., may prove of interest.

Steam-pressure 150 lbs. per sq. in.	Normal Load. I.H.P.	Normal Load. Average pressure referred to L.P. Cyl.	60 per cent. Overload. I.H.P.	60 per cent. Overload. Average pressure referred to L.P. Cyl.
This Engine is rated at. . . .	5,000	31·7	8,000	50·72
Or, using London County Council averages	5,056	32·05	7,584·7	48·09
Or, if using the Interborough averages	4,509	28·59	6,763	42·88

(Mr. Saxon.)

Fig. 5.

Mean Theoretical Diagrams for a Pair of Combined Twin L.P.-Vertical and H.P.-Horizontal Compound Engines.
Power House of Interborough Rapid Transit Railroad, New York.



Diameter of Cylinders, H.P. 42 inches, L.P. 86 inches. Stroke 60 inches.

Revolutions per minute, 75.

Ratio of Cylinder Areas, 4·19. Diameter of Piston Rods, 10 inches.

Steam Pressure at the Throttle, 175 lbs.

Load at best Efficiency, each Engine I.H.P., 3,750.

With 50% Overload, each Engine I.H.P., 5,625.

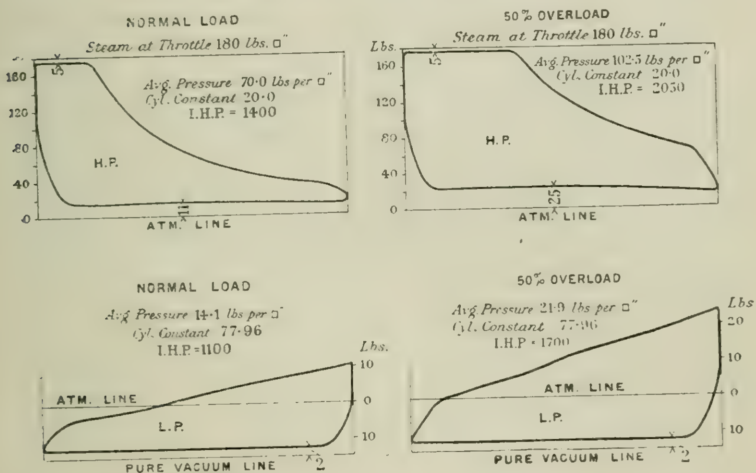
Average Pressure referred to each L.P. Cylinder :—

For 3,750 I.H.P., 28·59 lbs. For 5,625 I.H.P., 42·88 lbs.

In these diagrams the piston-rods are taken into account, and the clearances taken at 5% H.P. and 6% L.P. Cylinders.

Fig. 6.

Mean Theoretical Diagrams for a Pair of Combined Twin H.P.-Vertical and L.P.-Horizontal Compound Engines.
Power House of the London County Council.



Diameter of Cylinders, H.P. 33½ inches, L.P. 66 inches. Stroke 48 inches.

Revolutions per minute, 94.

Ratio of Cylinder Areas, 3·881.

Boiler Pressure, 180 lbs.

Load at best Efficiency, each Engine I.H.P., 2,500.

With 50% Overload, each Engine I.H.P., 3,750.

Average Pressure referred to each L.P. Cylinder:—
For 2,500 I.H.P., 32·06 lbs. For 3,750 I.H.P., 48·09 lbs.

Communications.

Mr. WILLIAM SCHÖNHEYDER wrote that the author, in describing the details of engines of several power-stations, gave some examples of the high-pressure cylinders being only one-half, or even less than one-half, the diameter of the low-pressure cylinders of compound engines. This the writer ventured to say was not in accordance with the best practice in this country.

Mr. SAXON, in reply to Mr. Schönheyder, would point out that the engines described were of the most economical type, and would compare with the most recent practice in this country for large stationary engines. The engines for the London County Council already referred to might be taken as an illustration of this, the sizes of the cylinders being 33½ and 66 inches respectively, which were practically one-half diameter when the piston-rods were taken into account.

SOME NOTES ON AMERICAN WOODWORKING MACHINERY.

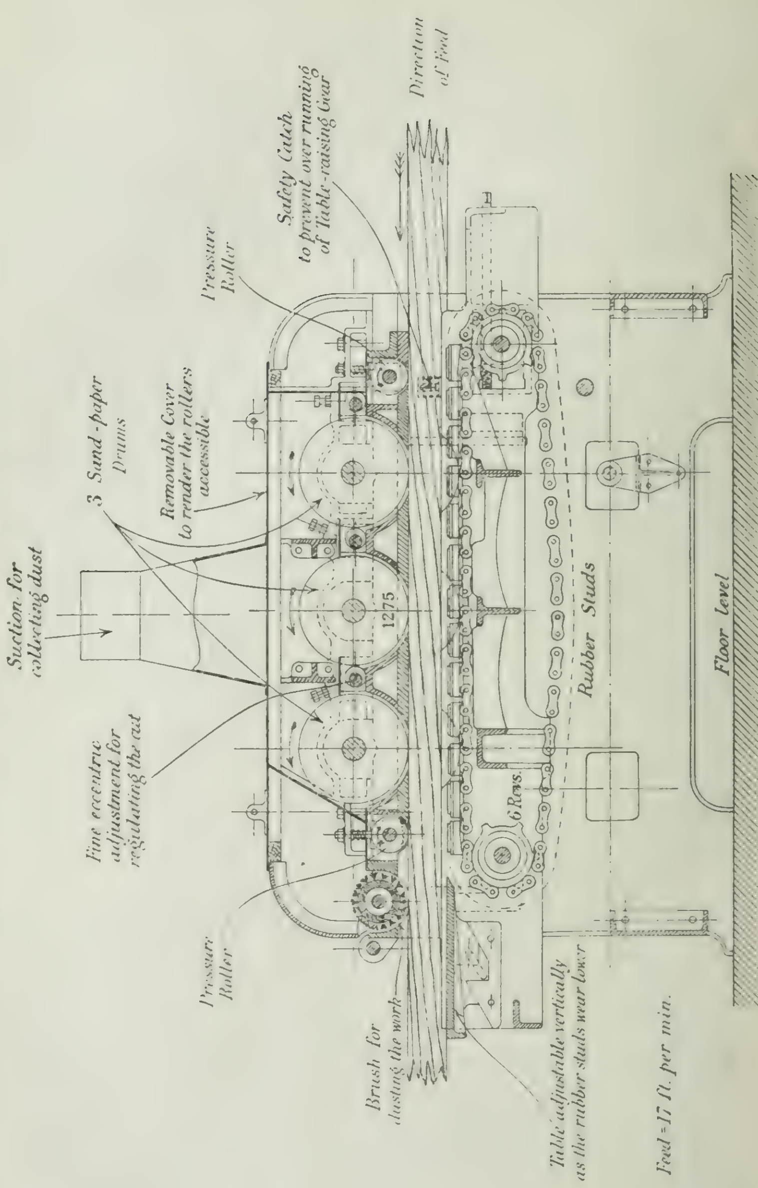
By Mr. W. STANLEY BOTT, *Associate Member*, of Coventry.

Between most of the woodworking machinery made in the United States of America and that made in this country there are several differences, and, while the majority of the American firms make machines which appear to be of lighter construction than those made by British firms, yet there are one or two makers who turn out a heavier class of machines and of a design more nearly approaching machine tools than has hitherto been manufactured in this country. Needless to say these are firms who have confined their attentions to machines for one particular class of work and have consequently been able to obtain greater perfection in the design than would otherwise have been the case. The author does not wish to convey the idea that machines of lighter construction are necessarily greatly inferior to the heavier machines, but merely that they form a cheaper grade. Anyone who decided to purchase a low-grade machine would probably find it satisfactory.

The two main differences one immediately notices between American and British machinery are: First, the almost universal use in the States of white metal bearings for all journals, no matter whether for saw spindles or the faster running cutter spindles; and, second, the size of the driving pulleys, which, from the author's observations, would give from 25 to 30 per cent. more driving power than the pulleys on similar machines of European make.

At the St. Louis Exposition the woodworking machinery exhibits were disappointing, the number of makers represented being limited to only a few American firms. The absence of large band mills—

Fig. 1.—Three Cylinder Drum Sand-papering Machine. Section through centre.

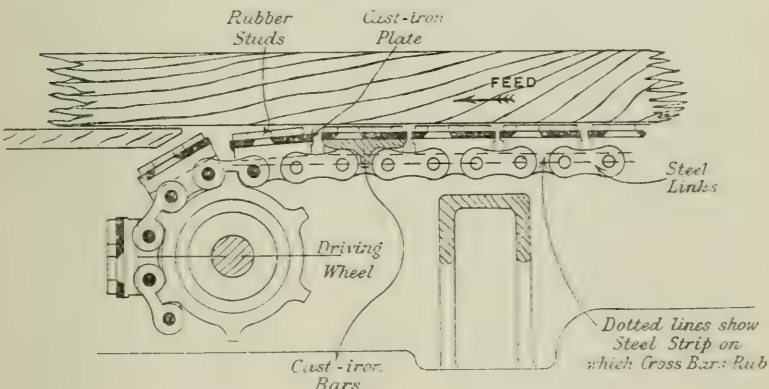


the machines which now play such an important part in the rapid and economical conversion of timber—was particularly noticeable.

A machine of much interest exhibited by the H. B. Smith Co. was a three cylinder drum sand-papering machine, in which the work is passed under the papering drums instead of over them as in a roller-fed machine. The work is fed forward by an endless band provided with a series of indiarubber studs which not only provide great feeding power, by virtue of the surface friction between the rubber and the work, but also provide all the pressure which it is

FIG. 2.

Section through Revolving Table showing Chains, Cross-bars and Studs, to a larger scale.



necessary to apply to keep the work up to the cut. In a roller-fed machine it is necessary to apply a heavy pressure to the rollers, which have a smooth surface, to ensure their feeding the work, and, in consequence, the fibres of the wood are bound to be compressed. This cannot happen with the endless feed described above, and it was mainly to overcome this defect that the new feed was designed. Another advantage this machine has over the roller feed is that, owing to the sand-papering drums being situated on the top of the machine, they are much more accessible when it is desired to change

the paper. Other advantages are claimed for the machine, and it is gratifying to learn that one of our English makers has been enterprising enough to acquire the patent rights for this country. Figs. 1 and 2 (pages 90 and 91) show a sectional elevation and detail of feed chain of the machine.

A type of machine which several makers were exhibiting was a power-feed rip saw, with plain or tilting table, to carry a saw up to about 20 inches diameter. The author believes that this type of machine was first brought out by Messrs. Greenlee, of Chicago, about the year 1889, and it is surprising that such a useful and handy machine is not, as far as the author is aware, made by any English manufacturer, although it is built by nearly every American firm. Messrs. Hall and Brown, of St. Louis, had a large exhibit, but the machinery contained no very striking novelties.

There was a useful looking chain mortising machine made by the New Britain Machine Co., and a double edging saw bench which carried two 18-inch diameter circular saws on the same spindle. To enable the cutting of wide or narrow boards, one of the saws whilst revolving was adjustable nearer to, or farther from, the other. Another feature of the machine was that both the saw and fence could be adjusted by the man feeding the machine while standing some distance away from the saws.

The panel planing or surfacing machines contained a feature of interest in the sectional top-feed rollers with which they were fitted. By these means several narrow pieces of wood of slightly varying thicknesses can be fed through the machine simultaneously—a fact which considerably increases the utility of any machine, and it is strange that this method of construction has not been more universally adopted in this country.

Some distinctive features of the planing and moulding machines exhibited were the fitting of chip breakers to nearly all cutter blocks, and the making of the square part of the blocks separate from the spindle, thus enabling the use of exchange blocks of various shapes. The pressures too were much simpler than those used in this country, but, on the other hand, they were not nearly so adjustable or flexible.

The exhibits of the Curtis Manufacturing Co., of St. Louis, comprised some ordinary circular log saws, one of which was fitted with a steam feed motion for actuating the log carriage, the action of which was controlled by a valve giving an almost instantaneous return motion.

Messrs. E. and B. Holmes, of Buffalo, showed a plant of cooperage machinery, including a machine for putting the heads in slack barrels without their being touched by hand. The heads are first placed one on top of the other in a receiver, the bottom one being automatically removed by a flat plate having a circular opening, into which the lowest head drops, and out of which it is lifted by a long hinged arm having a circular flat end provided with pneumatic suction of sufficient power to suspend the head. Then, by swinging round the hinged arm, the head can be brought over the barrel end and can be held in position there, until gripped by the barrel itself. This machine is also capable of driving on the permanent hoops, and removing the truss hoops, both of which operations are effected by means of six pendant arms which can be rapidly adjusted in and out to suit barrels of various diameters, and raised and lowered by power at the will of the operator. The machine can be run without skilled labour and takes 2 B.H.P. to drive it. It is also fitted with a suction fan for suspending the heads, and a convenient portable stand for carrying the hoops. Several varieties of hoop-driving machines were also shown in which claw-like arms can be brought down on to the hoops, and the hoops driven home with the greatest of ease. In some cases a double set of arms is provided, so that the hoops at both ends of the barrel can be driven at once. There was also on view a powerful machine for bending brewers' staves, consisting of two strong horizontal arms placed end to end, and on which the stave is laid. A pivot is provided on the underside of each arm, and the two central ends of the arms are connected by a link, which, when drawn down by the action of the machine, tilts up the outside ends of the arms and bends the stave. The stave when bent is made to retain its shape by a simple clip which hooks over the ends of the stave, and remains on them until after the barrel is set up and

trussed. The action of trussing releases the clips, which can then be used again. The machine is provided with fast and loose pulleys 30 inches diameter and 4 inches face, and has a capacity of from 8,000 to 12,000 staves per day. A useful machine for cleaning the outside of barrels consisted of an endless band of suitable abrasive material arranged to revolve in a vertical direction, the barrel being mounted horizontally between two chucks and revolved rapidly in an opposite direction to the band. On the band and the barrel being pressed together the exterior of the barrel was rapidly given a beautifully smooth surface. This machine has a capacity of about 1,000 barrels a day. Other machines on view were: a disc-stave jointer of an ordinary type, in which the stave is held up to a revolving disc, provided with a series of flat-edged knives; a chiming and crozing machine; and a head rounding and bevelling machine; none of which appeared to show any marked superiority over machines on the English market. An ingenious collapsible cone to facilitate the rapid placing of hoops over the ends of barrels was inspected, and also some useful barrel heaters, one of which was provided with a double table arranged to turn round, thus enabling a barrel to be always over the fire. With this revolving double table the barrels are placed on, and withdrawn from, the table which is momentarily away from the fire.

Messrs. Fay and Egan, of Cincinnati, who lay claim to being the largest manufacturers of wood-working machinery in the world, were not exhibiting, but, by the courtesy of the company, those members of the Institution who included Cincinnati in their itinerary were able to visit the works, which cover a large area. The various departments seemed somewhat scattered, but notwithstanding this fact, the amount of machinery turned out by the company appeared to justify their claim. In the works one noticed that the machine tools were all apparently working at their full capacity, every advantage being taken of the high-speed steel cutting tools. Grinding and milling machines were much in evidence, and some heavy milling was being done by an electrically-driven machine, which was surfacing and putting a slot in each of two square steel

cutterblocks, each about $4\frac{1}{2}$ inches wide, at a speed one would generally consider only suitable for cast-iron; this machine, so far as one could see, was unattended. Close supervision was evidently given by the principals to the design of the machines, and the author was shown a plain bandsaw with a new knife-edge sensitive tension and straining device; also a small boxmaker's self-acting cross-cut saw with an almost instantaneous return motion actuated by friction gear and controlled by a foot-lever. These machines he was told were much in advance of anything of a similar type yet brought out. When once the designs of the various machines made by this concern are perfected the machines are manufactured in quantities, and it is only by these means that cheapness has been secured. A noticeable feature of the machinery was the extensive use of cast-iron wherever possible, forgings being conspicuous by their absence.

The author had the pleasure of visiting the works of several other makers of woodworking machinery, among whom may be mentioned Messrs. Greenlee, of Chicago, who, at the time of the author's visit, were suffering from a strike and were also engaged in removing their plant to a new factory some few miles from Chicago. Messrs. Greenlee's speciality is machinery for railway-carriage and wagon work.

Messrs. E. B. Rich and Co., of Chicago, have a small works, and confine their attention solely to the manufacture of saw-sharpening machines and accessories.

Messrs. Pryibill and Co., of New York, are makers of general woodworking machinery, a feature of their business being the manufacture of machines for making piano action levers.

The E. C. Atkins Co., of Indianapolis, make a speciality of silver steel, and their works well repaid the author for his visit. The steel is made up into circular saws, large and small bandsaw blades, handsaws of all descriptions, cutters, etc. Some very ingenious machinery was seen for grinding with absolute accuracy the small teeth, which have to be interchangeable, for inserting in circular saws. A somewhat remarkable test mentioned to the author in

connection with this silver steel was that of a bandsaw blade which stood a strain of 127,000 lbs. per square inch at the braze.

In conclusion the author would like to take this opportunity of expressing his appreciation of the courteous manner in which he was everywhere received and conducted over the various works it was his good fortune to visit.

The Paper is illustrated by 2 Figs. in the letterpress.

NOTES ON THE VISIT TO AMERICA.

BY MR. CHARLES WICKSTEED, *Member*, OF KETTERING.

The one thing that must impress every visitor to America is that the Americans are great at great things. In method, in enterprise, in self-reliance, and in giant and rapid production, they are far ahead of the British. The author has been trying to think out the conditions of industry that have induced this superiority, in order to ascertain to what extent one is justified in trying to introduce American methods into this country, and to what extent the differences in the conditions here would make imitation folly; and the conclusion he has come to is that, although much can always be learnt from America—and the handsome contribution they have made to mechanical knowledge must be fully acknowledged—nevertheless, progress and evolution must be one's motto—revolution would be disastrous and impossible. The respective systems, broadly speaking, are those best adapted to the respective conditions—to transplant them would be fatal. The history of Great Britain, the character of its population, the size of the country, its natural resources, the nature of its trade, the opportunities for development and its fiscal policy, are all about as different from America as can be imagined. The author will trace briefly how these different conditions have brought specialization and swift production in large concerns to the perfection that is seen in America, and how it comes that a market can be made for such large quantities of one article, and why so much more pains have been taken by Americans to systematise their operations and introduce automatic machinery than have been taken on this side. He thinks that the rapid development of a vast and

rich territory, with an ever-increasing number of immigrants—mostly unskilled labourers—is at the root of the whole matter.

In pushing across the Continent, the work was, at first, naturally and inevitably of a temporary nature. If the railways that were laid through a wilderness, had not been made cheaply, they could not have been constructed at all; the same may be said of the towns. Thus temporary work began as a matter of necessity. After these first conditions were passed, another set of conditions arose, which drove industry in the same direction; the towns became large enough to justify work of a more permanent character, but the development was so fast that all idea of anything being permanently suitable for the altered conditions that were likely to arise was out of the question, so the temporary character of the undertakings to a great extent continued. This tendency was accentuated by the almost universal practice of building houses of wood, except in the business streets of the large towns. As the towns gradually became great cities, these influences lost hold, to a certain extent, and one now finds many undertakings of a permanent character; nevertheless, any attempt at durability is the exception. Men expect to get a quick return for their building, not knowing how soon buildings of a different nature may be wanted, and there are half a dozen influences still driving industry in the direction already denoted.

First, there is habit that people get inured to; then there is the rush and unrest of American life, which makes the people impatient of anything that will take long in doing; but perhaps the principal cause is the character of their labour. This is unskilled, unsettled, and dear, in comparison to that obtaining here; and for this reason cheap production and good work are only possible with the guidance of good heads, elaborate system, and the help of the first-class machinery, that can only be used in conjunction with a large turnover. The subdivision of labour has to be carried to a sufficient extent to enable raw hands speedily to learn to do their work. It appears to the author, broadly speaking, that all personal service is dear and bad; by personal service is meant labour that is not a part of an organised system, where the efficiency depends upon the individual, who must work on his own responsibility and not merely as a cipher

in a large system. Now, since repairs cannot possibly be systematised, as new work can, they come under the definition of personal service, and are so expensive that the Americans, comparatively speaking, do not repair; they scrap their things and buy new ones. The custom of scrapping, instead of repairing, inevitably tends to the making of things of a less permanent character. If people are constantly buying new things, they want to buy them cheap, so that they do not feel they have thrown away so much when they destroy them. But it may be asked: What has all this to do with the enormous American turnover? The author thinks that it has everything to do with it. One illustration will show what he means. He was told by Americans that their boots only lasted half as long as those in this country, and that they never repaired them. That means that they require four pairs of boots to one pair here, as British boots last double the time by soleing and heeling them. In America they have nearly double the population; this brings an output of boots for home consumption to nearly eight times that of this country. The same thing applies all round. Locomotives are scrapped in about ten years; shops are gutted and supplied with new plant; railway bridges replaced, and so on.

The rapid development of the country and the wonderful mineral wealth also tend to an abnormal proportion of a comparatively small variety of articles of first necessity. American industry is therefore driven into certain channels by conditions and necessities that do not arise here. It is driven into a course, which the author will not criticise more than to say that it is a course which has by no means a monopoly of advantages. In spite of every natural force tending to drive the trade of the country into gigantic and methodical production, a strange Providence has willed that the Government should step in and provide another; protection gives a powerful hand in two ways. First, it nurtures and protects trusts of a size and power that would be impossible without its aid. Second, it tends to limit the variety of articles manufacturers are obliged to make. The tendency of trusts, is of course, to carry on the businesses which they monopolise in fewer and larger establishments, making the sale under one management larger than it could otherwise be.

It also tends to put customers into the power of trusts, and to force them to take the articles they choose to supply; trusts will not go out of their way to accommodate people. But, independent of trusts, the author is convinced, from conversation he has had with a number of manufacturers, that protection has a distinct tendency to limit the variety and quality of articles of the same class that are put on the market. Manufacturers, who are manufacturers for their own country only—and 97 per cent. of the trade in America is home trade—naturally go for the main chance, because the things for which they get the readiest sale and which they manufacture to the greatest advantage are the things that they make. This tendency, of course, is intensified in works where system and subdivision of labour prevails. Thus protected from competition outside, they will not put themselves about to serve the few, and their customers, having no better choice before them, will probably not demand that which they cannot get—they can buy abroad at long prices or do without.

Without protection, things would be quite different. If trade were free, articles of great variety would be freely brought before the public, and American manufacturers would have to meet the competition or lose the trade. Here then is another potent factor that drives American trade into duplicate production that cannot be approached here—another potent difference between the two peoples. This makes the business of a trust easier, where trade can be sufficiently monopolised as to fetch its own prices; but the author thinks it makes the competition between small and independent firms far more grinding and wearing than in this country. The variety being limited, the accurate comparison of the value of articles produced becomes so much the easier. The greater variety of articles made, the more will people select the thing that they like the best, instead of that which is the cheapest. The Americans work with closed doors, and produce for their own people only; they sell abroad those goods that they make for themselves that happen to suit foreign markets; they do not and cannot cater for foreign markets in the same way as the British. This country—a free-trade nation—with its enormous export trade of manufactured goods, with its vast skilled and settled population makes an enormous variety of articles to supply needs in all parts of the world.

There are many things where the two nations might meet each other—or at any rate approach each other—to their mutual advantage. Here there is too little method, Americans often have too much; they will often begin with an elaborate system, before experience has taught them what is necessary. Manufacturers in this country are apt to begin with no system and build one up as necessity arises; that is the best plan, if they would but build faster. They increase their works only when they are driven to it, by the trade bursting the old premises; in America, they build large shops right ahead of any trade, and frequently court failure in the attempt. Here they are too slow in modernising their factories; in America, they can often show one how fast they are in this respect, but one also often finds out that the company has been reconstructed and that no dividend can be paid upon the original outlay. Americans value and reward brain work and encourage suggestions, instead of snubbing them; much might be learnt here, particularly in the matter of cutting down office expenses so much; a properly-managed office is not a drag upon the works, but acts as the fountain head.

In conclusion, the author wishes to state that he saw nothing to make him afraid of American competition, so long as English engineers will work with ordinary energy and foresight, adopting American methods so far as they may be suitable, without any attempt at slavish imitation. Industrially, he thinks, Americans appreciate themselves 25 per cent., whilst they on this side depreciate themselves at least at the same amount. It is a great mistake to think that the British are getting beaten, just because Americans are good in their department and are teaching them something in return for the immensely greater amount that they have learnt from the parent stock.

The Institution of Mechanical Engineers.

PROCEEDINGS.

February 1905.

The Fifty-Eighth Annual General Meeting was held at the Institution on Friday, 17th February 1905, at Eight o'clock p.m. The chair was taken by the Retiring President, J. Hartley Wicksteed, Esq., who was succeeded by Edward P. Martin, Esq., the President elected at the Meeting.

The Minutes of the previous Meeting were read and confirmed.

The President announced that the following two Transferences had been made by the Council:—

Associate Member to Member.

Duncan, William, ... Naauwpoort, Cape Colony.

Graduate to Associate Member.

Mogg, Henry Hodges, . . . Bath.

The following Annual Report of the Council was then read:—

ANNUAL REPORT OF THE COUNCIL

FOR THE YEAR 1904.

The Council have pleasure in presenting to the Members the following Report of the progress and work of the Institution during the past year.

With great regret the loss is recorded, in his eighty-fifth year, of Field-Marshal H.R.H. the Duke of Cambridge. He became an Honorary Member in 1892, and on several occasions showed the great interest he took in the welfare of the Institution.

During the year, His Majesty the King has conferred on Members of the Institution the following honours:—a Baronetcy upon Sir J. Fortescue Flannery, M.P.; and a Knighthood upon Mr. Joseph W. Swan, F.R.S., and Mr. William Lloyd Wise.

The total number on the roll of the Institution at the end of 1904 was 4,477, which, as compared with 4,211 at the end of the previous year, shows a net gain of 266. During the past year 460 candidates were elected, of whom 47 were formerly Graduates, and 2 elections became void, thus making 411 names added to the register. The total deductions have been 145, made up of 50 deceases during 1903 (see Report of 1903), 59 resignations which took effect on 1st January 1904, and 36 removals.

The increase in membership is a matter for congratulation, especially having regard to the higher standard of qualifications now required.

The Council wish to draw the attention of all classes of members to By-law No. 7, which reads as follows:—"The abbreviated distinctive Titles for indicating the connection with the Institution of Members, Associate Members, Graduates, Associates, or Honorary Life Members thereof, shall be the following:—for Members, M.I.Mech.E.; for Associate Members, A.M.I.Mech.E.; for Graduates, G.I.Mech.E.; for Associates, A.I.Mech.E.; for Honorary Life Members, Hon.M.I.Mech.E." Other abbreviations are not recognised as appertaining to this Institution.

The following fifty-four Deceases of Members of the Institution were reported during the year 1904:—

ATSUMI, SADAMOTO,	Osaka.
BANKS, GEORGE,	Manchester.
BAYNES, JOHN,	London.
BELL, SIR LOWTHIAN, Bart., LL.D., F.R.S.,	Middlesbrough.
BILLINTON, ROBERT JOHN,	Brighton.
BOWER, JOHN WILKES,	Leamington Spa.
BREWSTER, WALTER SECKFORD,	Sydney, N.S.W.
CAMBRIDGE, Field-Marshal H.R.H. THE DUKE OF (Hon. Life Member),	London.
CLACHER, DANIEL,	London.
COOKE, RUPERT THOMAS,	Manchester.
COOPER, WILLIAM,	Leith.
COWARD, EDWARD,	Manchester.
DAVIES, CHARLES MERSON,	Glasgow.
DAVIES, EDWARD JOHN MINES,	London.
DAVIS, GEORGE,	Manchester.
DITCHBURN, ROBERT (deceased 1903),	Bombay.
DOUGLAS, FRANK (Associate Member),	Delagoa Bay.
EVANS, ARTHUR GEORGE,	London.
FRY, ALBERT (deceased 1903),	Bristol.
GALLOWAY, CHARLES JOHN,	Manchester.
GORMAN, WILLIAM AUGUSTUS,	London.
GOULTY, WALLIS RIVERS,	Southwold.

Harvey, Julius,	London.
Heaton, George,	Birmingham.
Holcroft, Thomas,	Bilston.
Horsnell, Daniel,	London.
Howell, Joseph Bennett,	Sheffield.
Jameson, John,	Newcastle-on-Tyne.
Laws, William George,	Newcastle-on-Tyne.
Livock, Henry Arthur,	London.
Lloyd, Charles,	Bournemouth.
McClean, Frank, LL.D., F.R.S.,	London.
McDonnell, Alexander,	London.
Mitchell, James Frederick Bruce (Associate Member),	Bombay.
Myers-Beswick, William Beswick,	London.
Nasmith, Joseph,	Manchester.
Nelson, John,	York.
Oswald, Robert,	Tientsin.
Parker, Thomas, Jun.,	Manchester.
Pope, Joseph Gordon,	London.
Quin, Robert Cornelius,	London.
Rickaby, Alfred Austin,	Sunderland.
Roberts, William,	London.
Robson, George,	London.
Rouse, Frederick,	Peterborough.
Russell, Bridgman,	London.
Stewart, Duncan,	Glasgow.
Taylor, John,	Nottingham.
Tower, Beauchamp,	Brentwood.
Trueman, Thomas Brynalyn,	St. Ives, Cornwall.
Turner, Tom Newsum,	Nottingham.
White, Charles Fitzwilliam,	Lahore.
Widmark, Harald Wilhelm,	Helsingborg.
Wilson, Walter Henry,	Belfast.

Of these, Sir Lowthian Bell was elected a Member in 1858, Member of Council in 1870, Vice-President in 1872, and President in 1884; Mr. Rouse had been a Member from 1856, Mr. Bower from 1858, Mr. Howell from 1861, Mr. McDonnell from 1865, and Mr. Fry, Mr. Galloway, and Mr. Holcroft from 1866.

The Accounts for the year ended 31 December 1904 are now submitted (see pages 114–117 and 118), having been duly certified by

Mr. Robert A. McLean, F.C.A., the Auditor appointed by the Members at the last Annual General Meeting.

The total revenue for the year 1904 was £11,049 10*s.* 2*d.*, while the expenditure was £10,406 0*s.* 8*d.*, leaving a balance of revenue over expenditure of £643 9*s.* 6*d.*, exclusive of Entrance Fees £472 and Life Compositions £139 carried direct to Capital Account, and exclusive of the value of Subscriptions in arrear. The financial position of the Institution at the end of the year is shown by the balance sheet. The total investments and other assets amount to £72,175 0*s.* 3*d.*, and, deducting therefrom the £25,000 of debentures and the total remaining liabilities, £2,018 15*s.* 5*d.*, the capital of the Institution amounts to £45,156 4*s.* 10*d.*, including the £4,599 L. and N. W. Railway 3 per cent. and the £2,000 Midland Railway $2\frac{1}{2}$ per cent. Debenture Stocks set aside for Leasehold and Debenture Redemption Fund. The remaining investments consist of £1,945 12*s.* Midland Railway $2\frac{1}{2}$ per cent. Debenture Stock and £1,000 Consols ($2\frac{1}{2}$ per cent.). The certificates of the securities have been duly audited by the Finance Committee and the Auditor.

In compliance with an application from H.M. Office of Works, the Council have leased to that Department the upper floor and tower room of the building.

The First Report, by Professor David S. Capper, to the Steam-Engine Research Committee, of which Mr. William H. Maw is Chairman, has now been completed, and, together with a preliminary Report on Progressive Speed and Pressure Trials carried out previous to March 1896, will be presented at the March Meeting. The question as to whether this research should be continued, and in what direction, will be considered after the discussion on the present Report.

Since the presentation, in January 1904, of the late Sir William Roberts-Austen's last Report, the Alloys Research Committee, under the Chairmanship of Sir William H. White, has continued its work at the National Physical Laboratory. Dr. Glazebrook, Director of

the Laboratory, has arranged a series of investigations on specimens of Nickel Steel presented by Mr. R. A. Hadfield, a Member of the Committee. It is anticipated that a further Report will be presented this year by the Committee, communicating the results of these researches. Professor J. O. Arnold, Dr. A. Barr, Mr. F. W. Harbord, and Mr. J. E. Stead have been appointed to the Committee. Further investigations having great practical importance are now being considered.

Professor F. W. Burstall reports that the two specially constructed large gas-engines and a gas-holder erected in the new Power House of the University of Birmingham are now available for the Gas-Engine Research Committee's experiments. A scheme of experiments, indicating the methods of working, is under consideration, and it is hoped that the next Report will be ready for presentation at the opening of next Session. A generous gift of £100 towards the expenses of carrying on the research has been received from Dr. Ludwig Mond, F.R.S. The name of Captain H. Riall Sankey has been added to the Committee, of which Dr. A. B. W. Kennedy is Chairman.

The series of experiments on initial condensation in steam cylinders, which Professor T. Hudson Beare, Reporter to the Committee on the Value of the Steam-Jacket, is carrying out with special apparatus for the purpose, are in active progress, but are still incomplete. The results obtained so far, however, justify the hope that the Committee, under the Chairmanship of Mr. Henry Davey, will be able to present, during the year 1905, an interim Report dealing with the results obtained in the experiments on non-jacketed cylinders.

The Council desire to record their thanks to members and others who have given new books to the Library; also to the donors of various publications of Societies and Public Authorities, and of technical periodicals. A complete list of additions appears on pages 118 to 132. During the year the rules for borrowing books have been revised.

By invitation of the American Society of Mechanical Engineers, conveyed through their President, Mr. Ambrose Swasey, of Cleveland, and Secretary, Professor Hutton, of New York, the Annual Summer Meeting jointly with that of the American Society, was held in Chicago, where nineteen Papers were dealt with, and our own Proceedings have been enriched by four of the American contributions. The registered attendance at the Meeting was about 930, including the President and Mrs. Wicksteed and nearly 100 members of the Institution with their ladies. A Local Committee in Chicago arranged visits to works and places of interest in the neighbourhood, and members were subsequently entertained at Milwaukee, Cincinnati, Montreal, Boston, and the St. Louis Exhibition, where Colonel Watson, Commissioner-General for Great Britain, invited the members of both Institutions to a Garden Party at the British Pavilion, and the local Engineers' Club conducted a party on a steamer expedition up the Mississippi River. The American Society kindly handed to the visiting members the names of a large number of workshops to enable each member, during his stay in the United States and Canada, to make his own selection for Visits.

An additional short Summer Meeting took place in London on July 22nd, and the Annual Conversazione at the Institution was held on the following day.

Monthly Meetings were held throughout the year, with the exception of May to September. These meetings, with the Chicago Meeting, were occupied with the reading and discussion of the following Papers:—

Sixth Report to the Alloys Research Committee on the Heat Treatment of Steel; by the late Sir William C. Roberts-Austen, K.C.B., D.C.L., D.Sc., F.R.S.; completed by Professor William Gowland.

The Motion of Gases in Pipes, and the use of Gauges to determine the Delivery; by Mr. Richard Threlfall, F.R.S.

Compound Locomotives in France; by M. Edouard Sauvage.

The Burning of Town Refuse; by Mr. George Watson.

Refuse Destruction by Burning, and the Utilization of Heat Generated; by Mr. C. Newton Russell.

Some Theoretical and Practical Considerations in Steam-Turbine Work; by Mr. F. Hodgkinson.

The De Laval Steam-Turbine; by Messrs. E. S. Lea and E. Meden.

The Curtis Steam-Turbine; by Mr. W. L. R. Emmet.

Different Application of Steam-Turbines; by Professor A. Rateau.

Middlesbrough Dock Electric and Hydraulic Power Plant; by Mr. Vincent L. Raven.

Cast-Iron: Strength, Composition, Specifications; by Mr. William J. Keep.

The Effect of Strain and of Annealing; by Dr. William Campbell.

Experiments with a Lathe-Tool Dynamometer; by Mr. J. T. Nicolson, D.Sc.

Testing Locomotives in England; by Mr. G. J. Churchward and others.

Design and Test of a Modern Steam-Power Plant; by Mr. Edward G. Hiller.

A Scientific Investigation into the Possibilities of Gas-Turbines; by Mr. R. M. Neilson.

Impact Tests on the Wrought Steels of Commerce; by Messrs. A. E. Seaton and A. Jude.

Heat Treatment Experiments with Chrome-Vanadium Steel; by Captain H. Riall Sankey and Mr. J. Kent Smith.

The following Papers were accepted for publication in the Proceedings:—

The Measurement of direct Strains in tensile and compressive Test-pieces; by Mr. J. Morrow, M.Sc.

The Constitution of Metallic Alloys (Alloys considered as Solutions); by the late Sir W. C. Roberts-Austen, K.C.B., D.C.L., D.Sc., F.R.S., and Dr. A. Stansfield.

Malleable Iron Castings; by Mr. C. O. Bannister.

The Alloys of Tin and Antimony; by Dr. W. Reinders.

The Graduates held monthly Meetings during the Session 1903–04, and made three Visits to Works, including an excursion to Dover. The average attendance was about 34 at the Meetings and 30 at the Visits. Each Meeting was presided over by a Member of Council, except on one occasion, when the Chairman of the Graduates' Association took the Chair. The following Papers were read and discussed:—

The Design of a Town's Tramway Scheme; by Mr. William McDonald.

Heating and Ventilating Workshops on the Plenum System; by Mr. Walter H. A. Robertson.

Main and Auxiliary Steam Pipework for Power Stations; by Mr. Henry Baker.

Electric Passenger Lifts; by Mr. P. H. Stevens.
Two-Cycle Marine Petrol Motors; by Mr. Holbrook Gaskell, Jun.
The Manufacture of Linoleum Floor-Cloth; by Mr. Edward J. Stevenson.
A Method of Locomotive Valve-Setting; by Mr. G. C. Schultz.

The Papers by Mr. Stevens and Mr. Schultz have been awarded prizes by the Council.

At the February Meeting of the Graduates' Association, Mr. William H. Merrett, A.R.S.M., delivered an illustrated lecture summarising "The Work of the Alloys Research Committee," which has been published in the Proceedings.*

It is intended to hold the next Summer Meeting in Belgium, in view of the International Exhibition to be held at Liége in 1905.

The result of the Ballot for the election of President, two Vice-Presidents, and seven Members of Council, to fill the vacancies caused by retirement, will be announced at the Annual General Meeting.

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* Proceedings, 1904, Part 4, page 1319.

ACCOUNT OF REVENUE AND EXPENDITURE

AND

BALANCE SHEET FOR 1904.

Dr. ACCOUNT OF REVENUE AND EXPENDITURE

Expenditure.

	£ s. d.	£ s. d.
To Expenses of Maintenance and Management—		
Salaries and Wages	2,900 14 0	
Postages, Telegrams, and Telephone	526 5 4	
Heating, Lighting, and Power	169 0 0	
Fittings and Repairs	105 3 7	
Housekeeping	167 19 11	
Incidental Expenses	48 15 1	
		3,917 17 11
,, Printing, Stationery, and Binding—		
Printing and Engraving Proceedings	1,370 19 10	
Stationery and General Printing	689 12 4	
Binding	41 9 11	
	2,102 2 1	
Printing General Index 1885–1900	208 17 1	
		2,310 19 2
,, Rent, Rates, Taxes, &c.—		
Ground Rent	875 17 2	
Rates and Taxes	838 17 4	
Insurance	33 4 0	
		1,747 18 6
,, Meeting Expenses—		
American Meeting	280 3 0	
Printing	247 18 2	
Reporting	51 5 3	
Travelling and Incidental Expenses	40 15 5	
		620 1 10
,, Conversazione		166 2 3
,, Dinner Expenses		61 12 3
,, Gratuity to late Housekeeper		100 0 0
,, Graduates' Prizes		6 7 6
,, Books purchased		21 5 8
,, Engineering Standards Committee		50 0 0
,, Expenses in connection with Research Committees		310 6 0
,, Re-wiring Institution Building, final payment		27 15 6
,, Depreciation on Furniture and Fittings		64 14 1
,, Debenture Interest		1,000 0 0
,, Estimated value of Subscriptions in arrear, as per 1903 Balance Sheet	427 10 0	
Less amount of arrears actually received in 1904	426 10 0	
		1 0 0
Total Expenditure		10,406 0 8
,, Balance, being excess of Revenue over Expenditure (exclusive of Entrance Fees £472, and Life Compositions £139, carried to Capital Account, and exclusive of value of Subscriptions in arrear), carried to Balance Sheet		643 9 6
		£11,049 10 2

FOR THE YEAR ENDED 31ST DECEMBER 1904. *Cr.*

Revenue.

		£	s.	d.
By Subscriptions for 1904		10,551	0	0
,, Rent of Upper Floor of Institution Building		112	10	0
,, Interest, &c.—				
From Investments and Bank	130 7 1			
Income Tax refunded	12 18 5			
		143	5	6
,, Reports of Proceedings—				
Extra Copies sold		142	2	2
,, Donation from Dr. Mond for Gas-Engine Research		100	0	0
,, Debenture Transfer Fees		0	12	6
		£11,049	10	2

Dr. **BALANCE SHEET**

	£	s.	d.	£	s.	d.
To Debentures—						
250 *of* £100 *each at* 4%, *redeemable in* 1917, *or at par at any date after* 1st *Jan.* 1908, *on six months' notice to holder*				25,000	0	0
„ Sundry Creditors—						
Accounts owing at 31st *Dec.* 1904 (*since paid*) .	1,725	17	7			
Unclaimed Debenture Interest (*coupons not presented*)	118	7	10			
				1,844	5	5
„ Subscriptions paid in advance				174	10	0
„ Capital of the Institution :—						
Balance at 31st *Dec.* 1903	38,984	12	8			
Add :—						
Excess of Revenue over Expenditure for the year ended 31st *Dec.* 1904 . .	643	9	6			
Amount received from Life Compositions during 1904	139	0	0			
Amount received from Entrance Fees during 1904	472	0	0			
				40,239	2	2
Amount invested in £4,599 London and North Western Ry. 3% Debenture Stock, and £2,000 Midland Ry. 2½% Debenture Stock, with interest thereon, set aside for Redemption of Debentures and Institution's Leasehold Property, see contra				4,917	2	8
(*The Market Value of these investments and interest at* 31st *Dec.* 1904 *was about* £6,111.)						
				£72,175	0	3

Signed by the following members of the Finance Committee :—

W. H. MAW,

E. B. ELLINGTON,

H. GRAHAM HARRIS,

MARK ROBINSON.

AT 31ST DECEMBER 1904. *Cr.*

	£	s.	d.	£	s.	d.	£	s.	d.
By Cash—									
In Union of London and Smiths Bank—									
On Deposit				1,500	0	0			
,, Current Account . . .	345	19	3						
Add Paris draft not yet credited	3	0	0	348	19	3			
				1,848	19	3			
In the Secretary's hands				49	11	1			
							1,898	10	4
,, Investments . . . . *Cost*							2,401	8	7
£ 1,945 12*s*. *Midland Ry.* 2½% *Debenture Stock.* 1,000 2½% *Consols.* *The Market Value of these investments at* 31*st Dec.* 1904 *was about* £2,405.									
,, Investment of Amount set aside for Redemption of Debentures and Institution's Leasehold Property, *see contra* . . .							4,917	2	8
£4,599 *London and North Western Ry.* 3% *Debenture Stock, and* £2,000 *Midland Ry.* 2½% *Debenture Stock, cost* £4,826 19*s*. 2*d*. *with* £90 3*s*. 6*d*. *balance of interest thereon to be invested.* *These investments with their accumulating interest are set aside for the above purpose.*									
,, Subscriptions in arrear, *not valued.*									
,, Furniture and Fittings (*less depreciation*)							1,229	8	0
,, Books in Library, Drawings, Engravings, Models, Specimens, and Sculpture (*estimate of* 1893)							1,340	0	0
,, Amount in Union of London and Smiths Bank to meet unclaimed Debenture Interest (*coupons not presented*) . .							118	7	10
,, Proceedings—stock of back numbers, *not valued.*									
,, Institution House . . . . *Cost*							60,270	2	10
							£72,175	0	3

I certify that all my requirements as Auditor have been complied with, and I report to the Members that I have audited the above Balance Sheet, dated the 31st December 1904, and in my opinion such Balance Sheet is properly drawn up and exhibits a true and correct view of the state of the affairs of the Institution as shown by its Books.

ROBT. A. McLEAN, F.C.A.,
Auditor,
1 Queen Victoria Street, London, E.C.

17*th January* 1905.

WILLANS PREMIUM FUND.

Investment £159 8*s.* 5*d.* of India 3% Stock . . . . cost £165 5*s.* 0*d.*

Dr.	£ *s.* *d.*	*Cr.*	£ *s.* *d.*
To Balance, held in trust .	4 15 4	By Interest, 1904 . . .	4 15 4
	£4 15 4		£4 15 4

Audited, certified, and signed by the names on pages 116–117.

(For the Declaration of Trust, *see* Proceedings 1901, page 16.)

LIST OF ADDITIONS TO THE LIBRARY.

BOOKS (in order received).

Mechanical Shipment of Coal, by E. Herbert Stone; from the author.

The Metallurgy of Steel, by F. W. Harbord, with a section on the Mechanical Treatment of Steel, by J. W. Hall; from the authors.

Indian Electricity Act, 1903, by J. W. Meares; from the author.

Steam Turbine (2nd Edition), by R. M. Neilson: from the author.

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The following from the Engineering Standards Committee:—Interim Report, British Standards for Electrical Machinery; No. 6, Properties of British Standard Sections; No. 7, British Standard Tables of Copper Conductors and Thicknesses of Dielectric; No. 8, British Standard Specification for

Tubular Tramway Poles; No. 9, British Standard Specification and Sections of Bull-Headed Railway Rails; Statement of Work now in progress.

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Photograph of an Akroyd Gas Engine: from Mr. H. Akroyd-Stuart.

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The Autocar.
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Vulcan.
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The Engineering Record.
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The Iron Age (from Mr. W. H. Maw).
The Iron Trade Review.
Machinery.
Marine Engineering.
Marine Review.
The Patternmaker.
The Railway and Engineering Review.
Railway Master Mechanic.

ADDITIONS TO MUSEUM.

Two Outram Tram Rails from the Dalkey-Kingstown Outram-way; presented by The Commissioners of Kingstown Harbour.

Sample of Permanent Way, Manchester and Leeds Railway Pattern (now Lancashire and Yorkshire Railway); presented by Mr. W. B. Worthington.

(1) Derby and Birmingham, Length of rail showing scarf joint, with one joint and two ordinary chairs; (2) Short piece of Barlow Rail, 92 lbs. per yard; (3) Short length of Stephenson's Combination Rail, with one joint and two ordinary chairs and fastenings; (4) One Outram Plate; (5) One Outram Points; (6) One Barlow wrought-iron key; presented by the late Mr. J. Allen McDonald.

Three tram stones formerly laid in Belgrave Gate, Leicester; presented by Mr. E. George Mawbey.

Model of a two-cylinder horizontal Hick Saw-Mill Engine, of about 1845; presented by Mr. G. A. Vigers.

Model of Captain Rose's Patent Voice Tube; presented by Mr. Henry Chapman.

Barlow twisted chair-spike from the Midland Railway, put in round-top chair at Rugby, 1850, and taken out of use 18th January 1904; Cast-Iron Chair, dated 1833; Piece of old rail, Midland Counties Railway (1839), 5 inches × 2½ inches; North Midland, ordinary chair (1840), width at top 2½ inches; North Midland, joint chair (1840), width at top 3½ inches; Chair similar to Little North Western Line chair; Chair with piece of rail, Midland Railway (1874); Bolt and split key to attach to Birmingham and Derby Railway joint chair of 1839; Barlow Joint Chair (1844–9) used at the joints of the Standard permanent way of the Midland Railway, where carried on stone blocks (through Mr. Last of South Kensington Museum); Joint Chair from the "North Western" or Skipton and Morecambe line (1848–50), (also through Mr. Last); Chair from Newton Junction, Locke's pattern, of 1837; Birmingham and Derby Chair from Hampton, George Stephenson's pattern of 1836; presented by Messrs. C. E. and C. Stretton.

(1) Model of Conduit with Connections, Blackpool Electric Railway; (2) Compound Parallel Series Switch, Blackpool Electric Railway; (3) Model of Anti-Vibrator (see Plate 77, Proceedings 1897); presented by Mr. M. Holroyd-Smith.

The President, in moving the adoption of the Annual Report, said the Council would be very glad to hear it discussed in any aspect which the members might wish to draw attention to. The Annual Meeting was an opportunity for the members collectively and individually to make known to the Council any wishes they might have and any criticisms they might wish to make. He emphasised that portion of the Report which drew attention to By-law 7, pointing out the distinctive titles designating the various classes of membership of the Institution, the essence of which was that instead of using the simple letter M. as denoting "Mechanical," the abbreviation "Mech." was used, in the same way that the Institution of Civil Engineers used the designation M. Inst. C.E.

Mr. Edward P. Martin, President-Elect, formally seconded the motion for the adoption of the Report.

No remarks being made, the Report was unanimously adopted.

The President then presented the prizes to the two Graduates who had been successful in obtaining the award—Mr. P. H. Stevens for his Paper on "Electric Passenger Lifts," and Mr. G. C. Schultz for his Paper on "A Method of Locomotive Valve-Setting."

The President announced that the Ballot Lists for the election of Officers for the present year had been opened by a Committee of the Council, and that the following were found to be duly elected:—

PRESIDENT.

Edward P. Martin, ... Abergavenny.

VICE-PRESIDENTS.

Arthur Keen, ... Birmingham.
Sir William T. Lewis, Bart., . . . Aberdare.

MEMBERS OF COUNCIL.

George J. Churchward, ...	Swindon.
Henry Davey, ...	London.
William Dean, ...	Folkestone.
H. Graham Harris, ...	London.
The Rt. Hon. William J. Pirrie, LL.D., .	Belfast.
Sir Thomas Richardson, ...	Hartlepool.
Mark H. Robinson, ...	Rugby.

The Council for the present year is therefore as follows :—

PRESIDENT.

Edward P. Martin, ...	Abergavenny.

PAST-PRESIDENTS.

Sir Edward H. Carbutt, Bart., . . .	London.
Samuel Waite Johnson, ...	Nottingham.
Professor Alexander B. W. Kennedy, LL.D., F.R.S., ...	London.
William H. Maw, ...	London.
E. Windsor Richards, ...	Caerleon.
Percy G. B. Westmacott, ...	Ascot.
Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S., ...	London.
J. Hartley Wicksteed, ...	Leeds.

VICE-PRESIDENTS.

John A. F. Aspinall, ...	Manchester.
Edward B. Ellington, ...	London.
Arthur Keen, ...	Birmingham.
Sir William T. Lewis, Bart., . . .	Aberdare.
T. Hurry Riches, ...	Cardiff.
A. Tannett-Walker, ...	Leeds.

MEMBERS OF COUNCIL.

Sir Benjamin Baker, K.C.B., K.C.M.G., LL.D., D.Sc., F.R.S., ...	London.
Sir J. Wolfe Barry, K.C.B., LL.D., F.R.S., .	London.
Henry Chapman, ...	London.
George J. Churchward, ...	Swindon.
Henry Davey, ...	London.
William Dean, ...	Folkestone.
H. Graham Harris, ...	London.
Edward Hopkinson, D.Sc., ...	Manchester.
Henry A. Ivatt, ...	Doncaster.
Henry Lea, ...	Birmingham.
Michael Longridge, ...	Manchester.
James Mansergh, F.R.S., ...	London.
Henry D. Marshall, ...	Gainsborough.
The Rt. Hon. William J. Pirrie, LL.D., .	Belfast.
Sir Thomas Richardson, ...	Hartlepool.
John F. Robinson, ...	London.
Mark H. Robinson, ...	Rugby.
John W. Spencer, ...	Newcastle-on-Tyne.
Sir John I. Thornycroft, LL.D., F.R.S., .	London.
John Tweedy, ...	Newcastle-on-Tyne.
Henry H. West, ...	Liverpool.

The President said it was now his duty to vacate the Chair, and in doing so he derived the greatest pleasure in giving place to Mr. Martin. Mr. Martin was a man who had been "salted"; he had already been President of the Iron and Steel Institute. He was also a man of large experience and much travel, and one who knew pretty nearly all the quarters of the globe where mechanical engineering was much practised. As a matter of fact, Mr. Martin had been "in pickle" by the Council for that position for several years. Up to the present time his energies had been entirely absorbed in enormous responsibility in connection with mechanical engineering and iron and steel making; but now that his obligations in industrial affairs

(The President.)

had become somewhat easier, he was able to devote some of his boundless energies to the good work of conducting the prosperity of the Institution. He felt he could not vacate the Chair with greater pleasure in favour of any one than he did in favour of Mr. Martin.

Mr. WICKSTEED then vacated the Chair, which was taken, amid hearty cheers, by the new President, Mr. EDWARD P. MARTIN.

The PRESIDENT (Mr. Martin) thanked the members for the great honour they had done him in electing him President of the Institution of Mechanical Engineers, and trusted that, with their assistance and that of the Council, when his term of office ended he would have done no harm to the Institution.

Dr. ALEX. B. W. KENNEDY, Past-President, said that, while congratulating themselves on the new President and the new President on his election, it was at the same time a pleasurable duty to move a resolution familiar to the members attending the Annual Meeting: "That the best thanks of the Meeting be accorded to Mr. J. Hartley Wicksteed for the manner in which he has filled the office of President during the last two years." That motion certainly did not require any speech. The members themselves had seen Mr. Wicksteed's work during the time and they knew what it had been. He had been looking at the chart on the wall, and turning back to the years 1894–95,* when he himself had the honour of being President, he regretted to see that, although he thought they worked hard in those days, it was only at a much later date that the Institution began the great rise which was shown in the diagram. He had found the duties of President for two years somewhat laborious, but Mr. Wicksteed must have found them, with the enormously increased membership and with the new House to look after, very much heavier. In addition to carrying out the duties of President of the Institution at home, Mr. Wicksteed had, as was well known, the additional duty of representing, with other members, the Institution in America last summer. If the members were all

* Proceedings 1903, page 118.

as popular here as he understood Mr. Wicksteed was in America, they might congratulate themselves greatly. In Mr. Wicksteed the Institution had returned to something like the typical mechanical engineer of the days when the Institution was founded. Looking at the last few Presidents, first came Mr. Maw, an encyclopedia who knew everything! Sir William White was most distinguished in naval architecture; Mr. Johnson was a locomotive engineer; Mr. Windsor Richards was specially connected with metallurgy and iron manufacture; then came himself (Dr. Kennedy), a mere Jack-of-all-trades; but Mr. Wicksteed was a genuine mechanical engineer in the old meaning of the phrase, and of the kind that was known in days when mechanical engineering work first began. He was very glad that the Institution had again had the privilege of having a President of this type, as well as one who had devoted himself so thoroughly and heartily and with such very great success to the work which he had had to carry out, and he had great pleasure in moving the resolution which he had already read to the meeting.

Mr. WILLIAM H. MAW, Past-President, in seconding most heartily the resolution proposed by Dr. Kennedy, wished to emphasise everything Dr. Kennedy had said as to the admirable manner in which Mr. Wicksteed had performed his duties during the past two years. He (Mr. Maw) happened to have a great many friends amongst the leading engineers in America, and he had heard a great deal from them as to what went on when the members visited the States last year, and he had heard but one opinion expressed, and that was, that nothing could be more admirable than the manner in which the prestige of the Institution was maintained in America by Mr. Wicksteed. At the summer meetings in this country the President was usually supported by several Vice-Presidents and Members of Council; but it happened last year that only one Member of Council was able to accompany him to America, and therefore the work that fell upon the Past-President was much greater than it would have been under ordinary circumstances. But the task was well within Mr. Wicksteed's capabilities, and the whole meeting was a most thorough success, largely due to Mr. Wicksteed himself. In addition to having

(Mr. William H. Maw.)

secured ample recognition in America of the standing of the Institution, Mr. Wicksteed had also secured some very sincere personal friendships—friendships which he certainly would value, and which it was to be hoped he would long live to enjoy.

The President congratulated himself on his first duty being such an agreeable one—to put the resolution from the Chair. Mr. Wicksteed had taken the Institution safely to the United States and Canada, and in doing so had proved himself as good a pilot as he had proved himself a President. It was hardly necessary to point out the marked ability with which he had conducted the discussions on the various Papers presented to the Institution, and that ability would put his successor in a very awkward position in endeavouring to follow him.

The resolution was carried with acclamation.

Mr. Wicksteed thanked the members very heartily for their expression of good-will and appreciation of his work during his time of office and the manner in which he had fulfilled his duties, and also thanked the speakers for their kind remarks. He was very pleased to hear what Mr. Maw had said of the intelligence he had had from America. He knew that he had formed very cordial feelings towards the President of the American Society of Mechanical Engineers and many others whom he met, but he was not aware that he was credited with having been a good representative of the Institution. Mr. Martin had touched upon a matter on which he had prided himself more than anything else, namely, the character of the meetings and the discussions that had taken place during his years of office. He had often seen the Hall so full as to make him think that in a short time it would be too small for the Institution. During his Presidency the interest in the Papers and in the discussions had never flagged, and he did not remember any meeting that had not been well attended, or any Paper that had been presented that had not received an adequate and spontaneous discussion. Indeed, there was usually a good deal left over to be contributed to the Proceedings in writing. His feelings upon being invited to

undertake the responsibilities of the office were prompted by a sense of duty, and he expected to find it a strain. It would be an encouragement to his successor when he said that he had not found it to be in the slightest degree a strain; it had been almost a relaxation. To come up to the Council Meetings and to take part in the General Meetings had always been a refreshment. The reason of course was what no one else could know, namely, the strengthening, backing up, and relief from arduous work which the President received from the Council. The harmony enjoyed on the Council and with the members at the general meetings was so complete that every meeting had been an unalloyed pleasure. Now, on the completion of his term, he had made room for the new President by retiring to what was really in the constitution of the Institution the "House of Lords." During his somewhat long career in connection with the Institution he had been subjected to at least six contested elections, and it was by his survival and longevity that he had reached the position of President.

With regard to the Past-Presidents, although some of them were not seen so much as his predecessor, Mr. Maw and others, yet they were all of great assistance in many ways; they placed their abilities at the disposal of the Institution and worked for its interests. The work that was done by Members of Council, especially those Members of Council who lived in London—work on the Finance Committee, on the House Committee, on the General Purposes Committee, as well as on the Council—was very great. It was impossible for the members to know who did the work. Some of it was done by those who were not able to attend the evening meetings very frequently.

In conclusion, he wished most sincerely to express his thanks not only to the members for always keeping him in heart by their attendance and by the interest shown in the proceedings of the Institution, but to the Council of the Institution for the kindness and efficiency of the support they had given him on all occasions.

The President reminded the members that at the present meeting the appointment had to be made of an auditor for the current year.

Mr. Daniel Adamson moved: "That Mr. Robert A. McLean, F.C.A., 1 Queen Victoria Street, London, be re-appointed to audit the accounts of the Institution for the present year, at the same remuneration as last year, namely, twenty-five guineas."

Mr. E. Godfrey Brewer seconded the motion, which was carried unanimously.

The Discussion on the four Papers on the American Visit was resumed and concluded.

The Meeting terminated at a Quarter to Ten o'clock. The attendance was 132 Members and 54 Visitors.

SOME PHENOMENA OF PERMANENT DEFORMATION IN METALS.

BY MR. G. H. GULLIVER, *Associate Member*, OF EDINBURGH UNIVERSITY.

In making an ordinary tension test of a bar of metal, as soon as the yield-point is reached, the deformation becomes visible to the naked eye as the well-known "Lüder's lines." These lines have been very thoroughly investigated by Hartmann.*

In the experiments to be described flat steel bars were used, of a uniform thickness of $\frac{1}{8}$ inch, but of various widths from $\frac{1}{2}$ inch to 4 inches. All the bars had a smooth coating of mill scale. The steel employed, known as mild steel hoop, had an average yield-point at 18 to 20 tons per square inch, and a breaking load of 28 to 32 tons per square inch, with an elongation of 20 to 30 per cent. in 8 inches. The chemical composition varied somewhat with different bars, but an average analysis may be taken as: carbon, 0·20 per cent.; manganese, 0·25 per cent.; silicon, 0·03 per cent.

On testing such bars in tension, as soon as the yield-point is reached, the scale, being comparatively inextensible, begins to flake off in the places beneath which marked slipping is taking place in the metal. Thus these places show up as light lines against the dark background of oxide, and very clearly exhibit the progress of the deformation in the bar. Deformation generally occurs at a number of independent planes, and gradually creeps from both sides

* Hartmann, "Distribution des déformations dans les métaux soumis à des efforts." Paris, Berger-Levrault et Cie., 1896.

of each plane. Fine lines shoot sharply across the faces of the bar, often, though not always, beginning at the gripped ends. These lines increase in breadth, but not usually beyond a certain amount. Other lines, often at right angles to the length of the bar, form between the first ones, and finally the whole of the scale drops off, though the load may have been stationary. Sometimes much of the scale remains adherent until the test is far advanced. Figs. 1 and 2, Plate 3, are from photographs of flat tension bars and show the appearance of these lines. Sometimes, though more rarely, the deformation is propagated as a "strain wave" gradually creeping along the whole length of the bar, and no separate lines are distinguished. This effect is shown by Figs. 3 and 4, which are from photographs of specimens tested in compression; some independent lines have also appeared.

In the former case the lines, and in the latter the wave front, make a constant angle with the axis of the bar. If there were no friction this angle would be 45°, being the inclination of the planes of maximum shear; but owing to friction the angle of inclination to the axis is increased in the bars used to about 50°. The lines are, of course, traces of the planes of slipping on the faces of the bar, and are often visible continuously round all the faces, Fig. 5; in cylindrical bars they become helices, Fig. 6. Sometimes on one face of a bar lines appear which are perpendicular to the axis, but these are generally found to have the ordinary inclination on the two adjacent faces. Curvature of the lines, and irregularities in their inclination not infrequently occur, but are probably due to an imperfectly axial loading, to the proximity of the grips, or to a lack of homogeneity in the material. It is not usually possible to measure the inclination nearer than about one degree. The constant angle between the lines and the axis of the bar will be called α in the case of tension, and β for compression. It has been shown by Hartmann that for the same metal, $\alpha + \beta = 90°$.

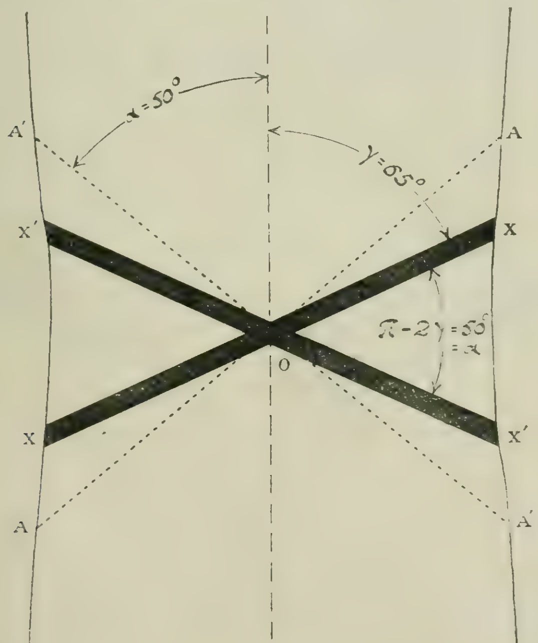
On continuing the test, a point of maximum load is reached at which a marked local constriction begins to occur. When this constriction becomes well developed, and the metal is not far from the breaking point, two straight depressions, XX, X′X′, Fig. 7,

often appear on the wide faces of the flat bar. This phenomenon is known as the "contractile cross," and is illustrated by Figs. 8 and 9, Plate 4. Sometimes only one of the depressions is markedly developed, Figs. 10, 11, and 12, while at other times there may be

FIG. 7.

Diagram to illustrate the difference between the primary lines of deformation and the contractile cross.

The dotted lines AA, A′A′ indicate the former, while the thick lines XX, X′X′ represent the cross. The horizontal angle XOX′ is seen to be equal to the angle between the lines AA, A′A′, and the axis.



three or more. The bar frequently, though not invariably, breaks along one or more of the depressions, Figs. 13 and 14 (page 144), and 15, Plate 5. It is noticeable that these marks are not inclined to the axis of the bar at the angle $\alpha = 50°$, but at an angle which will be called γ, and is about 65°.

An interesting peculiarity, which may not apply to all metals, is that the branches of the contractile cross being at 65° to the axis, the horizontal angles XOX′, Fig. 7 (page 143), are each 50°, *i.e.* equal to α for the metal considered. Hence a tensile stress along one branch of the cross would cause the other branch to become a plane of slipping as at the yield-point. The author must confess that he has been unable to persuade himself that such a tension does exist, though

FIGS. 13 and 14.

Flat Steel Bars, 3″ × ⅛″ broken by Tension.
These diagrams are tracings taken from the bars after fracture.

The two sloping lines in each show the edges of the contractile depression. The thick irregular line represents the fracture, which gapes considerably in the middle.

there generally seems to be a greater tendency for one than for the other branch of the cross to develop, especially as the ratio $\frac{\text{width of bar}}{\text{thickness of bar}}$ is increased.

A more remarkable circumstance is that which led to this investigation. Fracture usually occurs, in a ductile metal, at an inclination to the axis equal to the angle α. Thus the fracture of a prismatic bar is generally pyramidal, Fig. 16, Plate 5, whilst that of a cylindrical bar is helicoidal, Fig. 17, or conical, Fig. 18, according

as the metal shears along one of the helices of deformation, or along a cone tangential to a system of these helices, and whose semi-vertical angle is α. The minutely irregular surface of the fracture is composed of small elements, the surfaces of which are also inclined at the same angle α. Now it has been stated before that fracture in a flat bar, especially when the ratio $\frac{\text{width}}{\text{thickness}}$ is large, frequently takes place across the wide faces along the depressions forming the contractile cross, *i.e.* at the angle γ to the axis. This in itself is not remarkable, as the area at the bottom of the depression may be considerably less than that in the adjoining parts of the bar. But if we turn the bar through a right angle, and view it from the narrow face, we find the angle of fracture equal not to γ but to α. This is shown by Fig. 19. It is suggested tentatively that the angle α is due to slipping of the elementary crystals within the crystalline grains of the metal, and the angle γ to slipping of the grains themselves over each other.

Another reason for supposing that the process of slipping during a complete test varies in character is as follows:—The slip lines observed at the yield-point may frequently be seen after fracture if the surface of the bar is gently rubbed with fine emery paper. They are then found to be raised in relief, being brightly polished by the emery paper whilst the surrounding surface is left comparatively dull. If the inclination of these lines to the axis be measured at the end of the test, it is found to be not 50° but about 45°. The reason for this is that, after the slip lines are formed at the yield-point, they behave as though they were lines drawn on the surface of the bar. Since the bar increases in length and decreases in width, a sloping line drawn on the surface will alter its slope, and take a more nearly longitudinal direction. That this is the correct explanation was shown by scribing a series of lines on the polished surface of a bar at an angle of 50° to the axis. At the yield-point the usual slip bands appeared, and were seen to be, as nearly as possible, parallel to the scribed lines. During the remainder of the test this parallelism was preserved. On afterwards measuring the angle made by both lines and bands with the axis, this was found to have

changed from 50° to about 45°. The angle calculated from the elongation, which averaged 10 per cent. in parts remote from the constriction, is approximately $44\frac{1}{2}$°, the area of surface of the bar being assumed to remain constant. The angle α should thus always be measured at the yield-point when the slip lines are actually formed. In the constricted region of the bar the lines become curved, and are steeper. This experiment shows very strikingly that the increase of resistance along a plane of slipping is very soon sufficient to prevent further motion, thus giving rise to the well-known strain-hardening effects. The slip bands at the end of the test have a curious flame-like appearance. They are frequently tapered in width, and are generally divided by a narrow central line, which, from its comparatively dull appearance, must be below the surface of the broad flame-like band, Fig. 15, Plate 5. This line probably represents the original plane of slipping.

A result of the contractile cross phenomenon is the known fact that fracture usually begins at the middle of a bar. If both branches of the cross are well marked the depression is greatest, *i.e.*, the metal is thinnest, in the region of their intersection, and fracture consequently commences there. Partial fractures of this kind are shown in Figs. 8 and 9, Plate 4, and 20 and 21, Plate 5. In Figs. 9 and 21 the region of intersection is considerably removed from the middle of the bar. When only one branch develops it has not been found possible to stop the fracture before it is complete, but on afterwards placing the two halves of the bar together they gape a small amount, showing that in this case also rupture began in the middle, and that the second branch of the cross was probably present to a slight extent, Figs. 13 and 14 (page 144).

A large number of experiments show that both α and γ are independent of the length of the bar (unless this is so short that the influence of the grips is very great), of the ratio $\frac{\text{width}}{\text{thickness}}$ (between the limits of 4 and 32), and of the rapidity of loading (between the limits of 3 per cent. per minute and 100 per cent. in 5 seconds). Annealing generally allows the cross to develop further before fracture takes place, thus giving deeper depressions. Some very

good specimens have been obtained by alternate stretchings and annealings, Fig. 11, Plate 4. The effect of quenching is peculiar, and has not yet been thoroughly investigated.

Hitherto the lines occurring at the yield-point have been confused with the depressions forming the contractile cross, and it has been definitely stated by Hartmann that the grooves are due to a number of the lines occurring very closely together. That the two phenomena are distinct is shown :—

(1) By the large difference in the angles of inclination, α being equal to 50°, and γ to 65°, as indicated in Fig. 7 (page 143);

(2) By the corresponding difference between the angles of fracture on the broad and on the narrow faces of a flat bar, shown in Fig. 19, Plate 5;

(3) By the appearance after fracture of the first or α lines inclined at a large angle to the fracture which has occurred along the contractile depression, as shown by Fig. 15, Plate 5;

(4) By the results of some experiments not yet mentioned. Bars were loaded until the contractile cross appeared. They were then removed from the machine and annealed, thus obtaining a fresh coating of oxide. On reloading, at the yield-point the usual lines occurred at the angle $\alpha = 50°$, these lines distinctly lying *across* the contractile depression, and not *along* it, though sloping in the corresponding direction;

(5) By the non-appearance of the contractile cross as distinct grooves in cylindrical bars, and in rectangular bars in which the breadth and thickness are nearly or quite equal. The α lines are as distinct on these bars as on the previous ones.

In some further experiments it has been found possible to obtain the two phenomena together, but still quite distinct.

The subject is being pursued further, using different metals, and with the additional aid of the microscope.

The Paper is illustrated by Plates 3 to 5 and 3 Figs. in the letterpress.

MEMOIRS.

ROBERT JOHN BILLINTON was born at Wakefield on 5th April 1845. He served part of his apprenticeship with Sir W. Fairbairn and Sons, of Manchester, from 1859 to 1863, and the remainder with Messrs. Simpson and Co., of Pimlico, and Mr. S. Witham, Calderdale Iron Works, Wakefield, up to 1865; after which he went to Mr. Roland Child, mining and civil engineer, of Wakefield, with whom he remained till June 1866. He then became assistant manager to Messrs. Walker and Eaton, of Sheffield, and was there engaged in designing and erecting locomotives and general machinery. In 1870 he was appointed assistant to the late Mr. W. Stroudley, who was then locomotive superintendent of the London Brighton and South Coast Railway, under whom he took charge of the design and construction of locomotives and rolling stock for that line. In 1874 he obtained an appointment as assistant to Mr. S. W. Johnson, locomotive superintendent of the Midland Railway at Derby. This post he occupied until 1890, when, on the death of Mr. Stroudley, he was appointed locomotive, carriage, and marine superintendent of the London Brighton and South Coast Railway. During his term of office he introduced the powerful bogie express engines and also the bogie carriages running on that line. His death took place at his residence in Brighton, on 7th November 1904, in his sixtieth year. He became a Member of this Institution in 1888; he was also a Member of the Institution of Civil Engineers, the Iron and Steel Institute, and the Institution of Naval Architects.

WALLIS RIVERS GOULTY was born at Brighton on 27th June 1834, and was educated at Denmark Hill Grammar School, London. At the age of fourteen he commenced an apprenticeship of five

years at the Brighton Locomotive Works of the London Brighton and South Coast Railway, passing through the workshops and drawing office. At its termination he was engaged as draughtsman and ironworks manager at Palmer's Shipbuilding Works, of Jarrow and Wallsend-on-Tyne, remaining over four years with them. He next was appointed head draughtsman and assistant manager to Messrs. Peto, Brassey and Betts, of Birkenhead and London, with which firm he stayed until 1863, when he accepted the position of manager of the Millfield Engine Works, Sunderland. In 1865 he became manager of the Reading Iron Works, Reading, remaining in that position until 1869, when he was offered the post of assistant manager of the Fairbairn Engineering Co., Manchester. After being a year with that firm he decided to commence business in Manchester on his own account as a consulting engineer, and in 1875 he went into partnership with Mr. H. Sherley-Price, and carried on business with him as consulting engineers, valuers, and auctioneers of machinery, under the style of Wheatley Kirk, Price, and Goulty, with offices in Manchester and London. In 1899 he retired from business, and went to reside at Walberswick, near Southwold, Suffolk, where his death took place suddenly from heart failure on 31st December 1904, at the age of seventy.

Sydney Ainslie Hollis was born at Brighton on 18th July 1873. He was educated at private schools, at Brighton College, and the Crystal Palace School of Engineering. Subsequently he spent one year at University College, London. In 1893 he served a pupilage of three years in the workshops of Messrs. Yarrow and Co., Poplar, fitting and erecting engines for torpedo boats and destroyers, and in 1897 was appointed assistant engineer to Mr. T. Stewart, with whom he was engaged on surveying and setting out waterworks' schemes for Bloemfontein, and for Table Mountain. In 1898 he became assistant resident engineer on the construction of the masonry dam for Table Mountain, and was subsequently employed in setting out, measuring up, etc., other schemes. He returned to England in

1900, and became chief assistant to Messrs. Bailey-Denton, Son and Lawford, of Westminster, being engaged on various water and sewerage schemes. In 1902 he obtained the appointment of chief engineering assistant to the Bloemfontein Town Council, being principally engaged on the irrigation works of that town. His death took place at Bloemfontein, after an operation, on 4th February 1905, in his thirty-second year. He became an Associate Member of this Institution in 1903.

CHARLES HORSLEY was born on 30th May 1829 at Pye Bridge, Derbyshire, and was educated at Derby Grammar School. Upon leaving there he went as a pupil to Messrs. Graham and Co., Milton Iron Works, and thence to Messrs. Sylvestres. Shortly after this he assisted in the erection of the tubular bridge over the Menai Straits. He then joined Mr. Alfred Penny, whom he ultimately succeeded, as London agent and consulting engineer to Messrs. James Oakes and Co. of Alfreton, Derbyshire, which position he held until the day of his death. He invented a gas exhauster and also a syphon which have been extensively used in the gas world. He was one of the members of the Joint Committee of the Staines Reservoirs Works from 1898 to 1903. For many years he was an active member of the Magisterial Bench for Middlesex, and in 1887 was one of the sixty chosen to carry on the work during the time the Cities of London and Westminster were being amalgamated under the title of County of London. He, in conjunction with Mr. Torrance, was returned unopposed as one of the representatives of East Islington for the first London Council; he was chairman of several and director of many gas and water companies. His death took place at his residence in Highbury, London, on 4th January 1905, in his seventy-sixth year. He became a Member of this Institution in 1873; he was also a Member of the Institution of Civil Engineers, and President of the Society of Engineers in 1881.

WILLIAM GEORGE LAWS was born at the Manor House, Tynemouth, on 18th April 1836, and was the eldest son of the

late Cuthbert Umfreville Laws, of Prudhoe Castle, Northumberland. He was educated at Durham University. In 1853 he was articled to Mr. James Burnett of the engineering firm of Messrs. Thompson and Boyd of Newcastle-upon-Tyne, and served a four years' pupilage with him, afterwards remaining in his office till August 1857. On leaving Messrs. Thompson and Boyd's, he entered the office of Mr. John F. Tone, first as a pupil and afterwards as assistant, and was engaged on the surveys and Parliamentary Work for the Border Union Railway, Border Counties Railway and North British Railway (Wansbeck Section). In June 1860 he was appointed Resident Engineer on the Wansbeck Railway, on which he was engaged for five years, designing and carrying out all the works thereon. From 1865 to January 1867 he was engaged, under Mr. Tone, on the surveys for the Bristol and North Somerset Railway and Teign Valley Railway, besides other important works. In 1867 he entered into partnership with his brother the late Mr. Hubert Laws, and practised in Newcastle-upon-Tyne. This partnership lasted till 1874, and amongst the works carried out by them were private works for the Duke of Northumberland, the Scotswood, Newburn and Wylam Railway, and other railways and works. In 1870 he reported to the Shields Chamber of Commerce on the navigation of the Suez Canal. He was engineer jointly with Mr. Thomas Bouch for the Newcastle and Tynemouth Tramway Bills in 1870 and 1871; and he designed and superintended the erection of the railway bridge over the River Tyne at Wylam, connecting the railways on the north side and south side of the Tyne. Owing to the existence of coal workings near the surface, it was not considered safe to put piers in the river and the bridge consists of three arched girders of 240 feet span, springing from abutments near the water-level, from which the platform is hung by wrought-iron suspension bars carrying cross girders below. In 1874 he entered the North Eastern Railway Co.'s office as Chief Assistant to the late Mr. T. E. Harrison, and assisted in the carrying out of many important works, including the alteration and extension of Hartlepool Docks, the riverside railway on the north bank of the Tyne, the railway

joining Monkwearmouth and Sunderland, including the bridge over the River Wear, and the extension of the South Shields Branch of the North Eastern Railway with the new station.

In December 1881 he was appointed City Engineer for Newcastle-upon-Tyne, which post he held for 20 years. During this time many important works were carried out, and he was Engineer for the Tramways and Street Improvement Bills of 1892, 1895, 1899, and 1902. Jointly with the late Mr. Messent he prepared a scheme for re-building the quay wall on concrete well-monolith foundations, and successfully carried out several sections of this work. He also carried out many street improvements and introduced Australian hardwood paving into Newcastle. The Ouseburn Outlet Sewers for the drainage of Gosforth, &c., and the Refuse Destructor at Byker were important works undertaken and completed under his control. In 1885 he designed and built a floating hospital for the Tyne Port Sanitary Authority, and in 1893 one for the Tees Port Sanitary Authority. Under his direction the first portion of the overhead electric tramway system in Newcastle was laid down in 1900–1901.

In December 1901 he resigned the office of City Engineer and was appointed Consulting Engineer to the Corporation. His death took place on 22nd December 1904, in his sixty-ninth year, at his residence in Newcastle-upon-Tyne, from heart disease after a short illness. He had previously suffered from heart complaint from time to time. He was elected a Member of this Institution in 1874; and was also a Member of the Institution of Civil Engineers, and of the North of England Institution of Mining and Mechanical Engineers. He had been President of the Association of Municipal and County Engineers.

FRANK THEODORE MARSHALL was born in Newcastle-on-Tyne on 8th July 1866, and was the only surviving son of the late Mr. Francis Carr Marshall,* for many years head of the firm of Messrs. Hawthorn, Leslie and Co., of Newcastle-on-Tyne. He

* Proceedings 1903, Part 2, page 361.

was educated at Durham School, and, when sixteen years of age, entered as a premium pupil the above-mentioned works, of which he subsequently became engineering manager. After his practical training, he proceeded to London University, taking an engineering course under Professor Kennedy. He ultimately returned to join his father's staff, and succeeded him in 1897, being appointed three years later to a seat on the board of directors, as managing director. During the time that he had complete control of the works many successful designs were evolved, and many satisfactory warships and merchant vessels were engined. Amongst recent British ships for which he designed and constructed the machinery may be noted the battleship "Bulwark," four of the cruisers of the County class, and the cruiser "Duke of Edinburgh," as well as several foreign warships. In the construction of machinery for torpedo-boat destroyers he was particularly successful, and since 1899 the firm have constructed engines for about a dozen of these vessels, all of which have given satisfactory results. Although in his earlier years he was of robust constitution, for some time his health was failing, so that his death was not unexpected when it took place at his residence in Gosforth, Northumberland, on 10th February 1905, at the age of thirty-eight. He was elected a Graduate of this Institution in 1889, and was transferred to full membership in 1902. He was also a Member of the Institution of Civil Engineers, of the Institution of Naval Architects, and of the North-East Coast Institution of Engineers and Shipbuilders.

GABRIEL JAMES MORRISON was born in London on 1st November 1840, and studied at the Glasgow University under Professor Rankine and Professor Thomson (afterward Lord Kelvin). Whilst there he was awarded a prize for experimental investigation and another for his answers on the theory of the electric telegraph; a further prize was given him by his fellow-students for general eminence in the ordinary business of the Natural Philosophy class. During this period he served an apprenticeship of five years with Messrs. Robson Forman and McCall, civil engineers of that city. He was selected by Sir William Thomson as one of the

electricians to represent him in Newfoundland, and was present at the laying of the first telegraphic cable across the Atlantic Ocean. For a year and a half he had the responsible charge as resident engineer of the Glasgow and Milngavie Railway. In 1863 he left Glasgow, and joined the staff of Mr. (afterwards Sir James) Brunlees, in London as one of his principal assistants, which position he occupied for 11 years. During this time he acted as resident engineer on the following works: Cleveland Railway, Lynn Dock, Clifton Extension Railway; he also prepared the surveys of the Volo and Larissa Railway, and was engaged on the following works (making many of the principal drawings): Lynn, Avonmouth and Whitehaven Docks, San Paulo, the Central Uruguay and Honduras Railways, and in this country the Solway Junction, the Lynn and Sutton and Spalding and Bourne Railways. During this time he was also much engaged in parliamentary work and the preparation of parliamentary plans, estimates and the collecting together of engineering evidence. He read at the meeting of the British Association in Belfast, in 1874, a Paper on "The Adoption (for general purposes of navigation) of Charts on Gnomonic Projection instead of on Mercator's Projection," which eventually resulted in his book on Maps referred to hereafter.

On the completion of the Clifton Extension Railway, he commenced practice on his own account in Westminster, but shortly afterwards received an offer to proceed to China as engineer-in-charge of the first railway laid down in that Empire—namely between Shanghai and Woosung. This was successfully laid, and the line was opened on the 1st July 1876; soon afterwards it was purchased by the Chinese Government and torn up by them, the materials being shipped over to the Island of Formosa, where they were allowed to rust away. He then established himself in business in Shanghai as a civil engineer, making trips to Formosa, Peking, and the interior of China, visiting officials and endeavouring to introduce a system of trunk lines in China. He prepared many plans and estimates in connection therewith, and in fact devoted all his energies to this purpose. He also took

great interest in "China's Sorrow," the Yellow River, which has caused such devastation, and he made careful examinations and reports to the Chinese Officials, and wrote two Papers on this subject which were read before the Institution of Civil Engineers in 1888. Much of the above-mentioned work was carried out in connection with or in addition to his ordinary business in Shanghai. In 1885 he entered into partnership with Mr. F. M. Cratton, F.R.I.B.A., and the firm of Morrison and Cratton, civil engineers and architects, was for many years connected with the largest and most important works carried out in Shanghai and other places in China. The local affairs of Shanghai occupied a share of his attention, and he occupied a seat for many years as a member of the Shanghai Municipal Council. He was the first President of the Society of Engineers and Architects in Shanghai, and had also been Commandant of the Shanghai Volunteer Corps. He left Shanghai and returned to London in 1902, and was associated with Sir John Wolfe Barry, K.C.B., and partners, as consulting engineers of the Shanghai-Nanking Railway.

Mr. Morrison joined the Society of Arts of London in 1900, and the Society's silver medal was conferred upon him in 1903 for his Paper on Maps and Charts. He also wrote a book upon the same subject, which has been published by Edward Stanford. His death took place at his residence in Kensington on 11th February 1905, at the age of sixty-four. He became a Member of this Institution in 1900; he was also a Member of the Institution of Civil Engineers, being awarded the Telford Premium and receiving the "Watt" medal in 1876. He was elected a Member of the Institution of Electrical Engineers, and was a Member of the Royal Institution and a Fellow of the Royal Geographical Society. He frequently contributed Papers and articles to the leading technical societies and to the press, particularly to the "North China Daily News."

William Beswick Myers-Beswick was born in Leeds on 2nd July 1850. He was the son of the late Mr. W. H. N. Myers, of that City, and took the surname of Beswick on inheriting the

ancient manorial property of Gristhorpe, near Filey in Yorkshire. He was articled to Messrs. Filliter and Rofe, hydraulic engineers, of Leeds. Afterwards he went through the civil engineering course at Berlin University; and on his return to England he joined the staff of the late Mr. John Fraser, of Leeds, whose practice he continued to carry on in conjunction with his brother-in-law, Mr. Henry J. Fraser, until the death of the latter, when he continued in practice by himself, with offices in Westminster and Leeds. For the last four years he was in partnership with Mr. W. P. Morison and Mr. G. F. Murray, both of whom had co-operated with him as assistants for some years. His practice comprised the construction of many important branches of the Great Northern Railway in Yorkshire and Leicestershire, and works for the North Eastern and London and North Western Companies, including some heavy tunnelling, viaducts and a great variety of bridgework. On the Pudsey Branch he constructed the Tyersall Bank, the extreme height of which attains to 110 feet, and contains about 600,000 cubic yards of material. He also conducted an extensive parliamentary and general consulting practice. He was a magistrate for the North Riding of Yorkshire, and took a great interest in county affairs. His death took place at Malvern, where he had gone for the benefit of his health, on 27th December 1904, at the age of fifty-four. He became a Member of this Institution in 1888; and he was also a Member of the Institution of Civil Engineers.

Joseph Nasmith was born in Manchester on 22nd April 1850, and received part of his education at the old Mechanics' Institute, afterwards serving his time as an engineer and millwright with Messrs. Wren and Hopkinson, of Manchester. He then obtained further experience as an engineer at various works in other parts of the country, including some time spent in Portsmouth Dockyard. From that date he was always extending his knowledge of spinning and weaving appliances, and was ranked as one of the highest authorities on these subjects. His knowledge was recognised when he was appointed in 1896 Examiner in Cotton Spinning for

the City and Guilds of London Technical Institute. In 1890 he started in business as a consulting engineer, particularly in textile work, and at the same time became editor of the "Textile Recorder," for which journal he wrote articles on almost every subject connected with the textile industry. Two of his books are recognised as standard works, namely, "Modern Cotton Spinning Machinery" and the "Student's Cotton Spinning." For many years he had been a member of the Manchester Association of Engineers, finally being elected President for the Sessions 1896–1897. During all that period he took a great interest in its progress, and frequently took part in the discussions. He was an ardent educationalist, and, as a co-optative member of the Technical Instruction Committee for Manchester, he devoted himself untiringly to the subject during the time the new Municipal Technical College was being erected and installed. For some years he had been managing director of Meters Limited, a company employed in the manufacture of gas meters, which owns several large works. In 1903 he was appointed chairman of the joint committee of the Manchester Association of Engineers and the Technical Instruction Committee of Manchester, which was then conducting some exhaustive tests on the relative values of tool steel.

For some considerable time his health had been very indifferent, but latterly a change for the better seemed to have set in, and it was hoped that he would soon be completely recovered. His death, however, took place suddenly at his residence on 8th December 1904, in his fifty-fifth year. He became an Associate of this Institution in 1889; was transferred to the class of Associate Members in 1894, and finally became a Member in 1897.

ROBERT OSWALD was born in Glasgow on 29th May 1855. He was educated at Milnes School and Mearns Street Science Classes, Greenock. In 1871 he commenced an apprenticeship of seven years with Messrs. John Scott and Co., engineers and shipbuilders, of Greenock, after which he was engaged from 1878 to 1882 in designing and constructing marine and other machinery for the

following Greenock firms—Messrs. Kincaid and Donald, Messrs. Caird and Co., Messrs. Steel and Co., and Messrs. Rankin and Blackmore. In 1882 he went out to China and was engaged in designing and constructing marine and land engines for Messrs. S. C. Farnham, of Shanghai, until 1888 when he entered the drawing office and became assistant superintendent in the Imperial Arsenal at Tientsin. From April 1900 to the outbreak of hostilities in the same year he acted as superintendent of the Arsenal in the absence of Mr. Stewart, and was responsible for the manufacture of mild steel, shells, field guns, sulphur, silver coins, steamers, engines, boilers, cartridges, smokeless powder, &c. For the services rendered by him to the sick and wounded and to the troops generally he received the special thanks of the Secretary of State for India and of Lieut.-General Sir Alfred Gaselee, Commander of the British Contingent China Field Force. In the autumn of 1900 he began on his own account in Tientsin as consulting engineer, surveyor, and architect. In a short time he had established a good business and had constructed some of the finest buildings in Tientsin, including the large Victoria Buildings, the Russo-Chinese Bank, and the Yokohama Specie Bank. In 1902 he took into partnership Mr. Loup and Mr. Lee, the firm being styled Messrs. Oswald, Loup, and Lee. In June 1904 he returned home, and illness supervening, his death took place in Edinburgh, on 12th December 1904, in his fiftieth year. He became a Member of this Institution in 1903.

FRANCIS PEACOCK was born in Leeds on 2nd April 1837. He commenced his apprenticeship at the New Holland Works of the Manchester, Sheffield and Lincolnshire Railway, and was transferred in 1852 to the Gorton Works. Two years later he entered the locomotive works of Messrs. Beyer Peacock and Co., but returned in 1856 to the New Holland Works as assistant foreman, where he remained four years. He then was appointed foreman of the Cyclops Works at Goole, and retained this position until 1865 when he went to sea as second engineer, subsequently becoming chief engineer. From 1867 to 1869 he

was in Messrs. Beyer Peacock's Works, and then was appointed locomotive superintendent of the Smyrna and Cassaba Railway, Asia Minor. In that position he remained for twenty-seven years, until his retirement. In 1897, however, at the request of the late Mr. H. R. Baines, and on the commencement of the construction of the Egyptian Delta Light Railways, he went out to Damanhour to take up the position of chief store-keeper and works manager, remaining in the company's service until June 1902. His death took place in Cairo on 14th February 1905, in his sixty-eighth year. He became a Member of this Institution in 1890.

James Edward Ransome was born at Ipswich on 13th July 1839. In 1856 he entered, as an apprentice, the Orwell Works at Ipswich, belonging to the firm then known as Ransomes and Sims. These Works were founded by his grandfather, Robert Ransome, the inventor of the chilled plough-share, in 1789. In 1860, on the completion of his apprenticeship, he became identified with the management of the plough and implement department of the business, and during the next twenty years or so he represented the firm at the many competitions in the ploughing field which then took place between the leading plough manufacturers. It was largely due to his efforts and ability that his firm succeeded in securing four out of the six first prizes offered at the Royal Agricultural Society of England's Show at Newcastle in 1864, and a prize in each of the seven divisions for ploughs at the Leicester Show in 1868. By 1882 the firm, with his assistance, had succeeded in winning no fewer than 435 prizes for single and double ploughs. He became a partner in 1868, and one of the managing directors when the business was converted into a company, under the title of Ransomes, Sims and Jefferies, on 1st January 1884. On the death of his brother, Robert Charles Ransome, in 1886, he held the chairmanship of the company conjointly in alternate years with his contemporary, John Robert Jefferies, until the death of the latter in 1900, when he became chairman, and held this office till his death. The practical part of his career was entirely identified with the

agricultural engineering, as distinct from the general engineering side of the business carried on by his company. Among his contributions to the literature of the subject was a Paper on "Ploughs and Ploughing," read before the Royal Agricultural College at Cirencester in 1865, in which he dealt exhaustively with the history of ploughs, and with the scientific construction of the modern implement. Another Paper on "Double Furrow Ploughs," read before the Framlingham Farmers' Club in 1872, dealt with the economy secured by the use of these ploughs as compared with single-furrow ploughs. Among the many improvements he introduced which have become admitted successes, and which have been, or will be, generally used on the expiry of the patent rights, may be mentioned the bowl wheel, for turning double-furrow ploughs; the divided or sectional plough-share, to effect economy in wearing parts; the taper tine, applied to cultivators and horse hoes, securing the rigidity of a fixed tine with the flexibility of a spring tine; and the divided cutter barrel in lawn mowers, by which the blades, being partly in a right-hand spiral and partly in a left-hand spiral, deliver the cut-grass centrally into the grass-box. He designed and organised the new plough and implement factory recently erected by his company, and made large extensions in their lawn mower factory. The trade carried on in this latter factory he managed entirely, and the business in motor lawn mowers now successfully established by his company is due to his initiative and energy. He was an active Member of the Council of the Royal Agricultural Society of England, the Council of the Smithfield Club, and the Council of the Bath and West of England Agricultural Society, besides being a member of many other agricultural societies in various parts of the country. He was a Justice of the Peace for the borough of Ipswich. His death took place in London on the 30th January 1905, in his sixty-sixth year. He became a Member of this Institution in 1886.

William Roberts was born at Trevanion, St. Mewan, near St. Austell, Cornwall, on 2nd June 1844. He was educated at

Dr. Drake's Academy, St. Austell, and afterwards at the College, Taunton. From 1861 to 1865 he served an apprenticeship at the Hayle Foundry, Cornwall, and then entered the service of the Manchester, Sheffield and Lincolnshire Railway under the late Mr. Charles Sacré, Chief Engineer. He remained in the drawing office until January 1869, when, through the recommendation of Mr. Sacré, he was appointed assistant general manager of the Buenos Ayres Great Southern Railway, which position he held until 1882, when he was appointed resident engineer and locomotive superintendent, retaining the former position until February 1885, and the latter until 22nd February 1884, it being decided at that time, as the result of the rapid development of the railway, that the engineering department should be sub-divided into Permanent Way and Works, and Locomotive, Carriage, and Wagon departments. During his service with this company from 1869 to 1885, the railway had increased from 70½ to 689 miles, including the very important extensions from Olavarria to Bahia Blanca and Tandil to Juarez, both of which were constructed during the time when he was the chief resident engineer of the company. On leaving the Buenos Ayres Great Southern Railway, he started in Westminster as a consulting engineer, and his practice included the Buenos Ayres and Mercedes Extension of the Buenos Aires and Pacific Railway (66 miles), the Venezuela Central Railway, the Argentine Great Western Railway, &c. In 1886 he became a director of the Costa Rica Railway and the North-West Argentine Railway. In 1888 he was instructed by the Board of the Argentine Great Western Railway Company to make a detailed inspection of and report on this railway, and in the following year was appointed general manager for three years during a period of serious difficulty. On the termination of this engagement, in 1891, he returned to London and subsequently joined the boards of several companies.

He was elected a director of the Buenos Ayres and Ensenada Port and Railway in 1894, and continued to serve in that capacity until its amalgamation with the Great Southern Railway in October 1898. In the same year he became one of the first

directors of the Imperial Portland Cement Company and took a great interest in the business, which he helped to found, his engineering knowledge being of considerable value in establishing the works, while his acquaintance among contractors and others materially assisted in making it a prosperous concern. In 1902 he became one of the first directors of the British Automatic Aërators Co., and through his instrumentality the form and simplicity of working the apparatus was greatly changed. His death took place suddenly while visiting in Upper Norwood, London, on 17th July 1904, at the age of sixty. He became a Member of this Institution in 1887; and was also a Member of the Institution Civil Engineers.

BEAUCHAMP TOWER was born on 13th January 1845 at Morton Rectory, in Essex, of which place his father was rector, and was educated at Uppingham School. He commenced his engineering career as a pupil at the Elswick Works, Newcastle-on-Tyne, in 1861, and, after the completion of his four years' pupilage, remained at the works as draughtsman for a few months, leaving in 1866 to take charge of the construction of a number of iron steamers at the Tyne Iron Works, where he remained until 1868. In 1869 he became assistant to the late Mr. William Froude, F.R.S., helping him in the preparation of the plant for the Admiralty Experimental Works at Torquay, and designed some of the apparatus. During this period he invented a speed indicator, which was fitted to several ships of the Royal Navy; he worked with Mr. Froude until 1872, when his health gave way, necessitating a year's trip in a sailing vessel to the South Sea Islands. On his return he carried out, in the years 1874–1875, an extensive series of experiments on torpedoes, the work being undertaken on behalf of Sir William Armstrong and Co. In 1875 his reputation as a careful and ingenious experimentalist led to his employment by Lord Rayleigh in some experiments in connection with his work on the "Theory of Sound." In 1877 he rejoined Mr. Froude's staff, and assisted in the development of the marine-engine dynamometer. Mr. Froude's health broke down, and he asked

Mr. Tower to accompany him in his voyage to the Cape, where he died. On Mr. Tower's return to England, in 1878, he commenced practice on his own account, and it was then that he developed his ingenious spherical engine,* which was largely employed for some years when high rotary speeds were needed. Early in the "eighties" he began the great work of his life, namely the construction of the gyroscopic "steady platform" for searchlights and guns at sea. The device was tested by the Admiralty, who encouraged the inventor to devote his time to these experiments; but who, finally, in spite of the success of the trials, decided that the apparatus was unsuitable for the service. The principal reason given for this decision was that the weight needed for the "steady platform" could be more usefully employed in carrying an extra gun or ammunition. Though naturally disheartened, he proceeded to adapt his invention for use on cross-channel steamers, and was engaged on this work at the time of his death.

Mr. Tower was best known to engineers in general by his experiments on journal friction, and during the period from 1882 to 1891 he was busily engaged in making experiments for the Committee on Friction Experiments, appointed by this Institution. The First Report,† in which the machine and method of experimenting were described, was presented to the Institution in 1883. The Second Report,‡ on the Oil Pressure in a Bearing, was read in 1885; the Third Report,§ on the Friction of a Collar Bearing, in 1888; and the Fourth Report,‖ on the Friction of a Pivot Bearing, was read in 1891. His death took place suddenly from hæmorrhage on the brain at his residence near Brentwood, Essex, on 31st December 1904, in his sixtieth year. He became a Member of this Institution in 1883; and was also a Member of the Institution of Civil Engineers, and of the Institution of Naval Architects.

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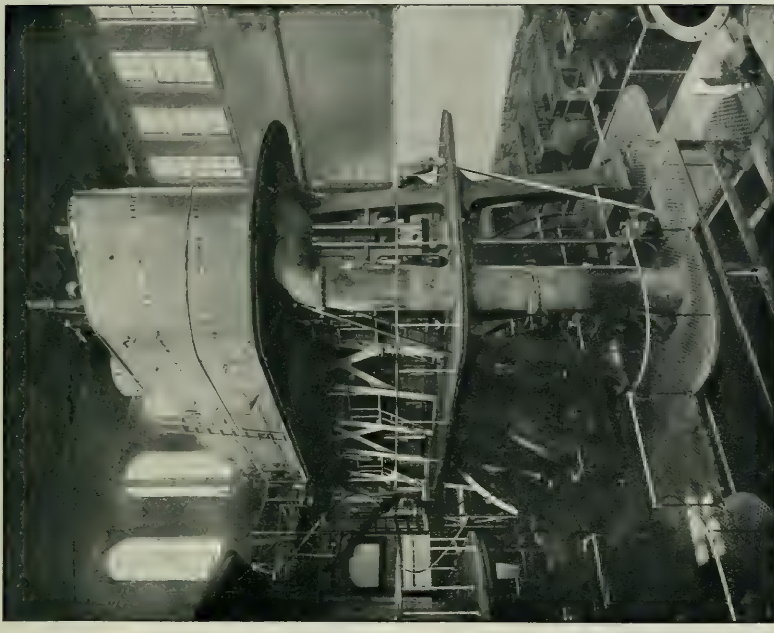
* Proceedings 1885, page 96.

† *Ibid*, 1883, page 632.

‡ *Ibid*, 1885, page 58.

§ *Ibid*, 1888, page 173.

‖ *Ibid*, 1891, page 111.



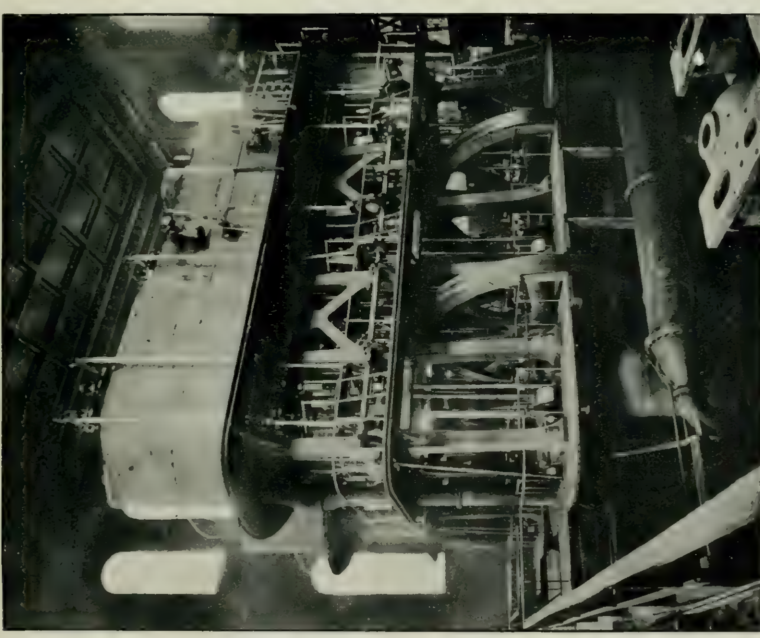
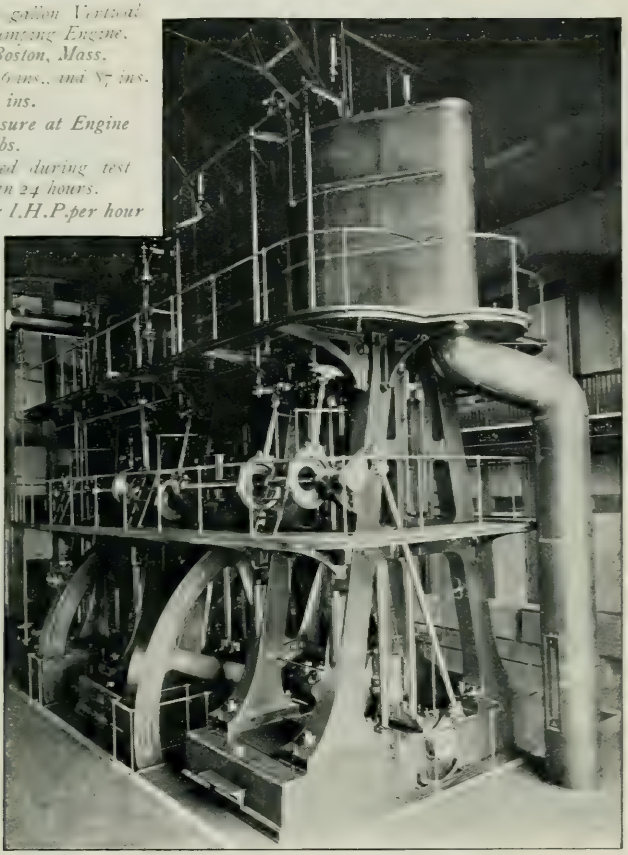


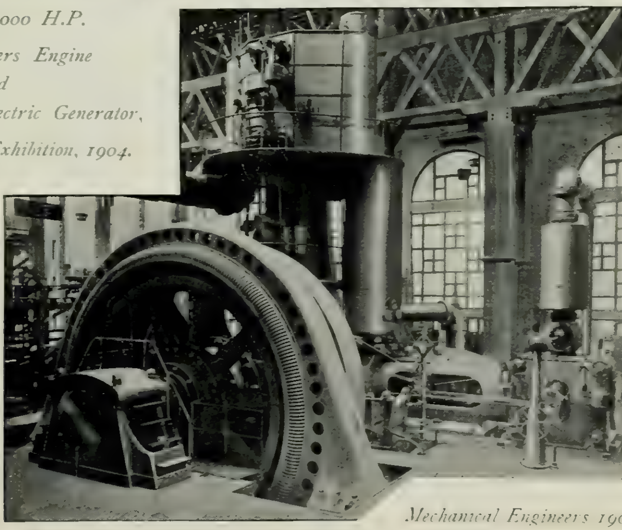
Fig. 6. *Pumping Engines at Bissell's Point, St. Louis. Diam. of Cyls. 34 ins., 62 ins., and 94 ins.*

Fig. 12. *30-million gallon Vertical Triple-Expansion Pumping Engine, at Chestnut Hill, Boston, Mass.*
Diam. of Cyls. 30 ins., 56 ins., and 87 ins.
Stroke 66 ins.
Average Steam Pressure at Engine 185.47 lbs.
Total Water Pumped during test 30,313,911 gals. in 24 hours.
Average Dry Steam per I.H.P. per hour 10.335 lbs.
Duty per 1,000 lbs. of dry steam 178,497,000 ft. lbs.
Thermal Efficiency of Eng. 21.63 per cent.



AMERICAN POWER-STATION ENGINES.

Fig. 4. *5,000 H.P.*
Allis-Chalmers Engine
and
3,500 Bullock Electric Generator,
at the St. Louis Exhibition, 1904.

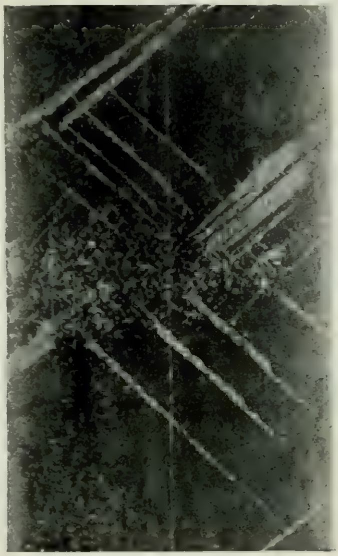


Figs. 1 and 2. *Flat Steel Bars, tensile stress 20 tons per square inch.*

The light bands are the lines of deformation, as shown by the mill scale flaking off the metal.

$3'' \times \frac{1}{8}''$

$4'' \times \frac{1}{8}''$

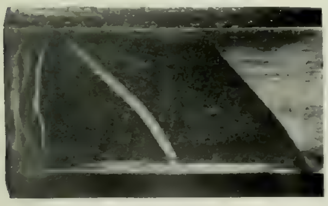


Figs. 3 and 4. *Cylindrical Steel Blocks, Polished and Blued.*

Compressive stress 12 tons per square inch. The deformed areas at the right ends were produced by gradually advancing strain waves. Some independent lines are shown at the left end of each block.

$1''$ *diam.* $\times 1\frac{1}{2}''$

A flat $\frac{3}{4}''$ wide planed on one side, afterwards polished and blued.



$1''$ *diam.* $\times 1\frac{1}{2}''$

The boundary of the right area is perfect.

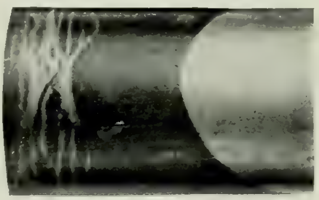


Fig. 5. *Prismatic Steel Block.* $1''$ *sq.* $\times 1\frac{1}{2}''$

Polished and blued. Compressive stress 12 tons per sq. inch. Many of the lines are continuous round the faces of the prism, showing that they are the traces of the planes of deformation.

Fig. 6. *Cylindrical Steel Bar.* $\frac{3}{4}''$ *diam.*

Polished and blued. Tensile stress 15 tons per square inch. The darker part in the middle of the bar has not yet yielded. The lighter deformation bands are seen to be helical.

Mechanical Engineers 1905.

Flat Steel Bars.

Fig. 8. 2″ × ⅛″

The contractile cross is clear and symmetrical, and the commencement of fracture is shown at the intersection of the depressions.

Fig. 9. 4″ × ⅛″

The contractile cross is not coaxial with the bar. The short dark line at the intersection of the depressions shows the commencing fracture.

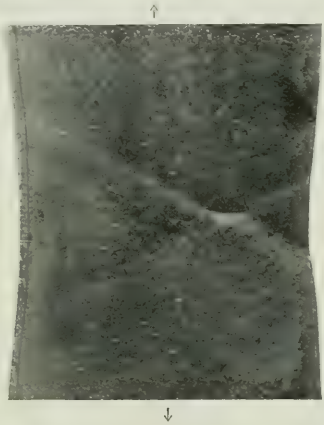


Fig. 10. 2″ × ⅛″

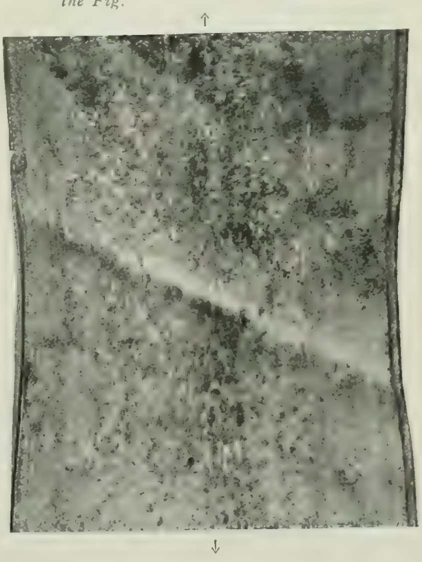
Only one of the depressions appears. The indications of the second one on the bar itself are very slight indeed.

Fig. 11. 2″ × ⅛″

Only one of the branches of the cross appears. This bar was stretched three times, with intermediate annealings. The minimum thickness of metal at the bottom of the depressions is ¼ the original thickness of the bar.

Fig. 12. 3″ × ⅛″

Only one depression appears, though the other may be felt on the bar, and is just visible on the right side of the Fig.



Steel Bars of various sections broken by Tension.

Fig. 15. $2'' \times \frac{1}{8}''$

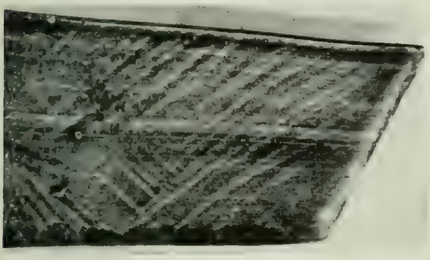
Fracture on right occurring along the contractile depression. Flame-like bands of deformation, as they appear at the end of the test, each show the central dark line which is probably the trace of the original plane of deformation.

Fig. 16. *Prismatic Bar.*

1″ square, showing pyramidal form of fracture. The vertical angle of the pyramid is 2 α.

Fig. 17. *$\frac{3}{4}''$ diam.*

Showing helicoidal form of fracture. Angle of helix is α.



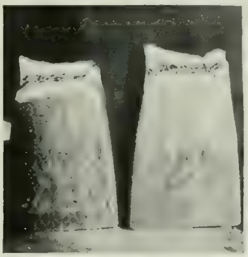


Fig. 18. *$\frac{3}{4}''$ diam.*

Showing conical form of fracture. The vertical angle of the cone is 2 α.

Fig. 19. $3\frac{1}{2}'' \times \frac{1}{2}''$

Fracture viewed from wide face, at the angle $\gamma = 65°$, to the axis.

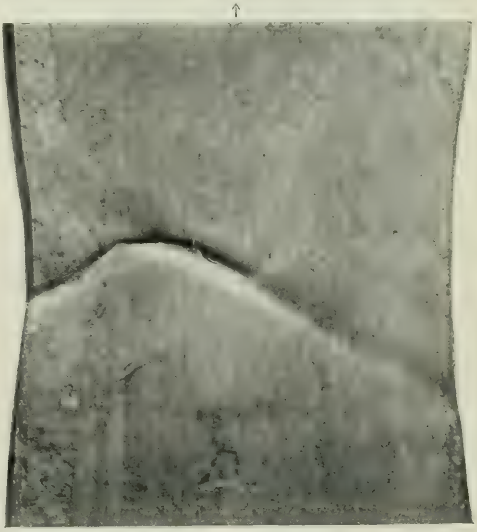
Fracture viewed from narrow face, at the angle $\alpha = 50°$, to the axis.

Figs. 20 and 21. *Flat Bars.*

The fracture is seen to be commencing at the intersection of the branches of the contractile cross.

$2'' \times \frac{1}{8}''$

$4'' \times \frac{1}{8}''$



Edw. P. Martin

PRESIDENT.

The Institution of Mechanical Engineers.

PROCEEDINGS.

17 March 1905.

An Ordinary General Meeting was held at the Institution on Friday, 17th March 1905, at Eight o'clock p.m.; Edward P. Martin, Esq., President, in the chair.

The Minutes of the previous Meeting were read and confirmed.

The President announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following seventy-nine candidates were found to be duly elected:—

MEMBERS.

Adey, John Atkins,	Manchester.
Bagnall-Wild, Ralph Kirkby, Captain R.E.,	London.
Keay, James Alfred,	Leicester.
Lawrie, Peter Stanley,	Penang.
L'Estrange, Arthur Henry Carleton,	London.
Meek, John,	Coventry.
Pratten, Frederick Edward,	Dartford.
Sharp, Robert Gordon,	Leeds.

ASSOCIATE MEMBERS.

ADAMS, FRANCIS ROBERT JOHN, . .	London.
ATKINS, HARRY FREDERICK, . . .	Shipley, Yorks.
BARBER, GEORGE ALFRED, . . .	Woolwich.
BUCKLEY, PHILIP, ...	Leeds.
CABENA, RICHARD HANSON, . . .	Croydon.
CROLL, JAMES, ...	Maui, Hawaiian Is.
DAVIDSON, BYRON MONTGOMERIE, . .	Cachar, India.
DIMMACK, ARTHUR, ...	Chester.
EGGERS, HERMANN FREDRIC CARL, . .	Dunedin.
FAWKES, RUPERT EDWARD FRANCIS, . .	Liverpool.
FERGUSON, RODERICK MORRISON, . .	Sunderland.
FLETCHER, AUBREY, ...	London.
FOSTER, EDGAR, ...	Derby.
FULTON, NORMAN OSBORNE, . . .	Glasgow.
GOODIER, HERBERT, ...	Bradford.
GOODWIN, ROBERT, ...	Basingtoke.
HAY, JOHN ANGUS, ...	London.
HEATON, WILLIAM HENRY, . . .	London.
HEWITT, ARNOLD ERNEST, . . .	Bradford.
HIGGINS, EDWARD PANTER, . . .	Stroud, Glos.
HUNTON, WILLIAM, ...	Rugby.
HUTCHISON, PERCY, ...	London.
JENKINS, EDGAR JACKSON, . . .	Rotherham.
KENNEDY, JAMES ALEXANDER, . . .	S. Sylhet, India.
KNOWLES, GUY JOHN FENTON, . . .	London.
LEE, HORACE PELHAM, ...	Coventry.
LONGWORTH, ALFRED EDGAR, . . .	Rangoon.
MARTY, FEDERICO, ...	Buenos Aires.
MARYON, ARTHUR THOMPSON, . . .	London.
MASON, FRANCIS BERNARD, . . .	London.
McCOOL, JOHN WILLIAM, . . .	Calcutta.
MERRALL, CHARLES EDDINGTON, . .	London.
MITCHELL, EDWARD ALBERT, . . .	London.
MOFFAT, WILLIAM GLOVER, . . .	Belfast.

Murray, George William, . . .	Bombay.
Newman, Arthur Dudley, . . .	Johannesburg.
Phillips, Frank Hugh, Lieut. A.O.D., .	Chatham.
Piercy, George Frederick, . . .	Birmingham.
Ratcliff, Wilfred, ...	Birmingham.
Rawlins, James Richard, . . .	Colombo.
Roberts, Henry James, ...	Port Talbot.
Sillar, Alfred Richmond, . . .	Colchester.
Smith, George Alfred, ...	Woolwich.
Smith, Harold, ...	Manchester.
Smith, Louis William, ...	Leiston, Suffolk.
Smith, Matthew Sidney, . . .	S. Melbourne, Victoria.
Swan, William Robert, . . .	Penang.
Taylor, George Stevenson, . . .	London.
Tritton, William Ashbee, . . .	Magdeburg-Buckau.
Turner, Ernest William, . . .	Peterborough.
Uttley, Edwin Abraham, . . .	Bulawayo.
Wall, Charles, ...	London.
Williams, George Bransby, . . .	London.
Willmer, Ernest Edward, . . .	Quilon, S. India.

GRADUATES.

Bathe, Cecil David Dalrymple, . .	Crewe.
Buckton, Ernest James, . . .	London.
Butterworth, Joseph, ...	Manchester.
Chadwick, George Herbert, . . .	Buenos Aires.
Clench, Edward Claude Shakespeare, .	London.
Homan, Arthur Knox, ...	Dublin.
Kininmonth, Colin Peter, . . .	Manchester.
Lane, Harry Joseph, ...	London.
Larkin, Leslie, ...	London.
Mallett, Arthur Henry, . . .	Bristol.
Mowll, Harold Havelock Savignac, .	London.
Myers, Archibald Charles Tracey, .	London.
Stanier, John Hamilton, . . .	Gateshead.
Swinney, Herbert, ...	Chepstow.

Waddy, Albert Wilfred, ...	London.
Walker, Charles Albert, ...	London.
Williams, Hugh Richard, ...	London.

The President announced that the following six Transferences had been made by the Council since the last Meeting:—

Associate Members to Members.

Ambler, Ratcliff Vincent, ...	Iquique.
Armistead, Thomas Webster, . . .	Liverpool.
Bale, John Henry Fooks, ...	London.
Cooper, Thomas, ...	London.
Craig, Alexander, ...	Coventry.
Rushton, James Lever, ...	Bolton.

The following Paper was read and partly discussed:—

"First Report to the Steam-Engine Research Committee"; by Professor David S. Capper, *Member*, of London.

The Meeting terminated at Twenty minutes to Ten o'clock. The attendance was 160 Members and 94 Visitors.

PROCEEDINGS.

31 March 1905.

An Extra General Meeting was held at the Institution on Friday, 31st March 1905, at Eight o'clock p.m.; Edward P. Martin, Esq., President, in the chair.

The Minutes of the previous Meeting were read and confirmed.

The Discussion on the "First Report to the Steam-Engine Research Committee," by Professor Capper, was resumed and further adjourned.

The Meeting terminated at Ten o'clock. The attendance was 91 Members and 41 Visitors.

FIRST REPORT TO THE STEAM-ENGINE RESEARCH COMMITTEE.*

BY PROFESSOR DAVID S. CAPPER, *Member*, OF LONDON.

The Steam-Engine Research Committee was constituted at the instance of the late Mr. Bryan Donkin to investigate and carry out research upon the Initial Condensation in Steam-Engine Cylinders. With this object a French firm undertook to construct an engine embodying the ideas of Mr. Donkin, and to lend it to the Committee for a series of research experiments. This engine was provided with three valves—first, one to admit steam during lead; secondly, one to open at the commencement of the stroke and to act as the admission valve, and thirdly, an exhaust valve. By supplying the first and second valves from separate boilers Mr. Donkin hoped that the steam required to replace initial condensation might be separately measured. The French firm at the last moment found that the engine had been so costly in construction that they were unable to fulfil their promise, and this form of experiment had to be abandoned. The Committee then decided to accept the offer of the authorities of King's College, London, to provide an engine of more ordinary design and place it at their disposal for experimental purposes. Through the kindness of Messrs. Marshall, Sons and Co., of Gainsborough, a special engine was obtained at cost price, and erected in the Engineering Laboratory at King's College.

* Incorporating the results of experiments at King's College, London, on Jacketed and Unjacketed Cylinders.

Description of Engine.—The engine thus obtained is a horizontal compound engine. The cylinders, which are side by side, are $6\frac{1}{2}$ inches and $11\frac{1}{4}$ inches diameter by 14 inches stroke, and the connecting-rods drive cranks placed at right angles. The arrangement of the engine and connections is shown in Fig. 1 (page 175).

Each cylinder is separately jacketed on the barrels and the ends, the supply and drain from the ends being separate from that for the barrel. Each cylinder is fitted with a Meyer expansion-valve adjustable by hand so that the cut-off can be separately varied between one-quarter and five-eights of the stroke. By grid valves on admission and exhaust sides, either cylinder can be arranged as a simple engine, and by blocking either of the Meyer plates the engine can be made single-acting. In any of its varied adjustments the engine is as nearly as possible an ordinary commercial engine, clearance volumes and contact surfaces being kept as small as possible. The clearance volumes for the high-pressure cylinder are 0·025 of a cubic foot at the front, and 0·033 at the back; and for the low-pressure cylinder 0·053 of a cubic foot at the front, and 0·056 at the back.

On the trials here recorded the low-pressure cylinder was not in use, the engine being run as a single-cylinder engine exhausting into a condenser, with the vacuum reduced to 2 to 3 inches of mercury. In this way the back pressure in the cylinder was kept constantly at atmospheric pressure.

The volume swept through by the high-pressure piston is 0·269 of a cubic foot at the back end, and 0·254 at the front, after deducting the volume of the $1\frac{1}{2}$-inch diameter piston-rod. The clearance space is therefore 12·4 per cent. of the cylinder volume at the back, and 9·8 per cent. at the front end.

The flywheel is 5 feet in diameter and water-cooled. To ensure steady running at slow speeds, a second flywheel, 7 feet in diameter, was provided and fitted in halves, so that at speeds above 100 revolutions it could be readily removed. But after the preliminary trials the larger flywheel was found unnecessary and was removed, as, within the range of speeds required, the engine ran perfectly steadily without it.

Boiler, Condenser, etc.—The boiler available was a Davey-Paxman semi-portable locomotive working up to 150 lbs. pressure per square inch, and capable of evaporating about 1,000 lbs. of water per hour. The condenser is a cylindrical copper condenser with 50 square feet of cooling surface, the tubes being externally cooled. It was kindly presented by Messrs. J. I. Thornycroft and Co. and the trustees of the late Mr. Donaldson, the Worthington feed- and air-pumps being presented by the Worthington Pumping Engine Co., and the steam traps by Messrs. Geipel and Lange, and the Lancaster Trap Co.

Scheme of Experiments.—The Committee decided that the first series of trials should be made with the engine arranged as a single-cylinder high-pressure engine, non-condensing jacketed, the second series being a repetition of the first series but without jackets. After a careful study of previous experiments, it was further determined that the variables should be temperature and speed, cut-off and all other conditions being kept constant. Temperatures of 245° F., 280° F., 315° F., and 350° F., were chosen, so as to give equal intervals between successive trials of the series. These temperatures correspond to about 27, 49, 84, and 135 lbs. per square inch absolute respectively at the engine steam-chest. The chosen speeds were 50, 100, 150, 200, and 250 revolutions per minute, corresponding to piston speeds of about 117, 234, 350, 467, and 584 feet per minute respectively. For reasons given below, it was not found possible to adhere absolutely to these speeds and temperatures.

Preliminary Trials.—A large number of preliminary trials were made to determine the best cut-off, exact speeds, and temperatures, which could be accomplished with the plant, and to find the best methods of adjusting and working the measuring apparatus, etc. It was found that it was impossible to extend the range of speeds to the lowest limit of the engine, namely, 25 revolutions per minute, without interfering with the upper limit, and it was likewise found that at the lowest temperature and pressure the auxiliary pumps could not be worked. At the upper limit of pressure and lower

limit of speed, and at the lower limit of pressure and upper limit of speed, trouble was found in keeping the conditions quite steady. After numerous attempts, it was finally found necessary to work the boiler at a slightly higher pressure than that actually required, and to get the exact and steady temperature in the steam-chest by slight throttling at the engine stop-valve.

At the lowest temperature of the series and in one or two other cases this throttling was sufficient to cause superheating, to which further reference will be found below. The cut-off which was required to obtain the largest range was found to be three-eighths of the stroke, and this was adhered to throughout both series.

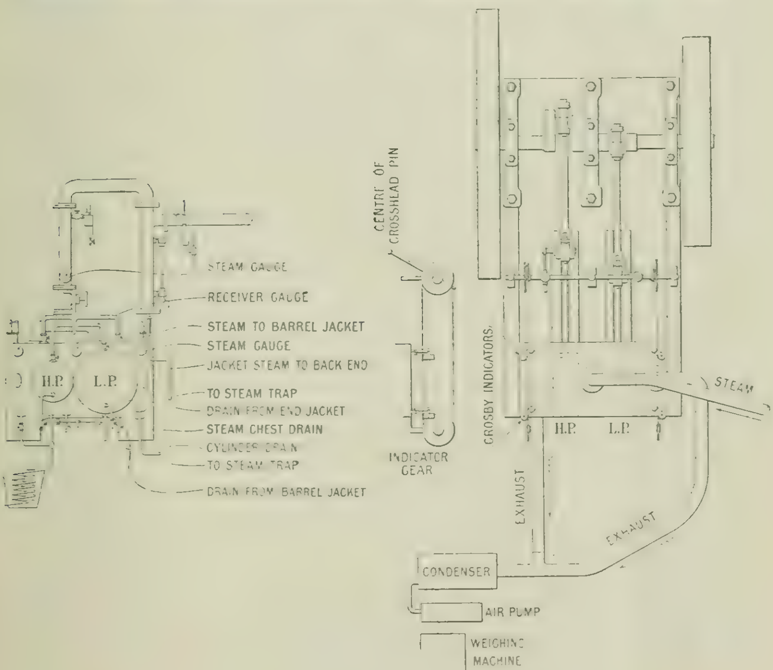
Arrangement of Plant.—The arrangement of the plant is shown diagrammatically in Fig. 1. Steam is supplied to the engine from the boiler above described through a steam pipe of 3 inches internal diameter. The total distance between the flange of the main stop-valve on the boiler and that on the engine was 47 feet. The whole of the pipe including all flanges is lagged for half its length with Leroy's covering $1\frac{3}{4}$ inches thick and the remainder with magnesia $1\frac{1}{2}$ inches thick. The pipe is sloped downwards from the boiler towards the engine, so that any moisture may be deposited and carried in the same direction as the steam. A ∩ bend is inserted between the end of the pipe and the engine stop-valve, and one arm of the ∩ is continued downwards beyond the junction with the steam-pipe, so as to form a collecting chamber for any moisture which is travelling along the pipe.

A gauge-glass is inserted in this separator, and a drain cock at the bottom opens communication with a steam trap, or with a measuring vessel. After experiment it was found most satisfactory to pass the discharge from the separator through a coil of pipe placed in a cooling bucket, so as to prevent the escape of vapour and ensure the whole of the moisture being measured. It was thus possible to measure with extreme accuracy any accumulation of water in the separator, and no trial in which this was above $2\frac{1}{2}$ per cent. of the whole steam discharged from the engine was accepted as satisfactory. Beyond the ∩ bend a wire-drawing calorimeter was inserted, and a

secondary measurement made at this point so as to check the readings of the separator. Arrangements were at first made to put a heating coil under the steam-pipe, so as to ensure dry steam being supplied, but the measurements made with the separator and the calorimeter showed that the steam supply from the boiler was so uniform that the heating coil was unnecessary.

FIG. 1.

Diagram showing General Arrangement of Experimental Plant, King's College.



Exhaust.—The trials being non-condensing, the air-cock on the condenser was opened so as to admit air and reduce the vacuum to the required extent. The discharge from the condenser was measured in a tank placed on a platform weighing machine, and records were taken every five minutes. Experiments were frequently made to determine

any leakage in the condenser, and after the tubes had been specially packed no difficulty was experienced in keeping the condenser tight. The pressures were measured by Bourdon gauges inserted one at the back of the main stop-valve and one on the steam-chest, and by a mercury gauge placed upon the condenser. All steam-gauges used were calibrated at intervals under steam on the mercury column in the laboratory, and the readings given in the Tables are the corrected readings after allowing for the errors so found.

Thermometers were placed in the steam-pipe and in the condensed water, and these were also calibrated in the laboratory. The indicator gear was attached as shown in Fig. 1 (page 175), the cylinders being positively driven, without the intervention of a spring, by steel piano wire passing round a drum on a rocking shaft. An indicator was placed on each end of the cylinder, and the connecting-pipe was made as short as possible. The indicator springs used were all calibrated under steam on the mercury column, and the indicated horse-powers have been worked out to the corrected scale of the springs used. All the diagrams were taken with soft lead pencil upon glazed paper so as to reduce as far as possible friction on the pencil point. Throughout the trials the low-pressure piston-rod was uncoupled, so that the high-pressure engine ran entirely independently without having to drive the low-pressure piston. The brake gear consisted of a rope wrapped completely round the water-cooled flywheel, the fall being attached to a spring balance which was frequently calibrated during the experiments by standard weights. The brake was lubricated by paraffin oil applied between the observations as uniformly as possible. Speed and not H.P. being fundamental, at each pressure the load and the lubrication were adjusted so as to keep the speed as nearly constant as possible. The revolutions per minute were recorded by a positive counter and checked at intervals.

Method of Conducting the Trials.—Observers were placed at the boiler gauge, the engine gauges, the separator and calorimeter, at the indicator, at the brake, at the condenser, and at the condensed-water tank, so that observations of the readings of all the instruments

could be taken at frequent intervals. Steam was raised in the boiler to the required pressure, and the engine having been started and run for some time until it was running steadily under the required conditions of speed and steam pressure, the trial was commenced and observations were taken every five minutes for half-an-hour. If the conditions varied during the run to any considerable extent the trial was continued until a steady run of twenty minutes to half-an-hour was obtained. If the trial then seemed generally satisfactory, the conditions were altered and a further trial was run.

It was not found possible to carry out more than about two trials on any day, owing to the demands upon the staff at King's College, and the large number of students who had to be dealt with in the laboratory. For the same reason the trials could not be conducted from day to day, but intervals of a week and more had often to elapse between consecutive trials. If on working out any trial any of the conditions or observations were found to vary beyond defined limits, the trial was rejected and repeated. In most cases the trials were divided into two, so that a careful comparison of the duplicate results could be made. Any trial which did not show uniformity throughout and accord well with the required conditions was not accepted.

Over 100 trials have thus been carried out and, of these, 38 have been selected as most closely satisfying the conditions laid down. Detailed observations and calculated results of these 38 finally selected trials are given in the appended Tables 13 and 14 (pages 252 to 255).

Explanation of Tables.—The capital letters A, B, C, and D, have been chosen to denote the four series of trials at different steam temperatures.

A	denotes the series at		245° F.
B	,,	,,	280° F.
C	,,	,,	315° F.
D	,,	,,	350° F.

The suffix attached to each capital letter denotes the speed at which each trial of a series was carried out.

The Suffix	1	corresponds to	50	revolutions.
,,	2	,,	100	,,
,,	3	,,	150	,,
,,	4	,,	200	,,
,,	5	,,	250	,,

Each unjacketed series is denoted by the same letter and suffix as the corresponding jacketed series, the letter being repeated in the unjacketed series for distinction.

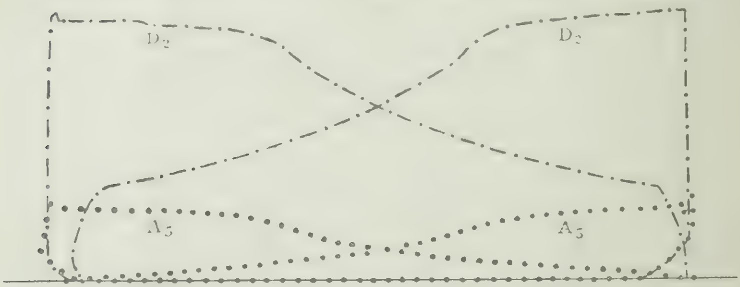
A_1 therefore means a trial at 215° F. 50 revolutions, jacketed.
AA_1 ,, ,, 215° F. ,, unjacketed.

and so on for the whole series.

FIG. 2.

Specimen Indicator Diagrams.

Trial D_2 (Jacketed ; 100 Revolutions per minute ; 150 lbs. Pressure.)
Trial A_5 (Jacketed ; 250 Revolutions per minute ; 35 lbs. Pressure.)



Method of working out Results.—From the whole of the diagrams taken on each trial a mean card has been constructed, and upon the mean diagram all calculations have been based. The diagrams were in most cases remarkably uniform, so that a card upon which the pencil had been allowed to trace a continuous diagram for half-a-minute shows hardly any measurable variation from a single card. Half-minute diagrams were thus taken in all cases so as to guide in the construction of the mean diagram. Copies of the actual diagrams and of mean calculated diagrams are shown on Fig. 2 and Figs. 3 to 12 (pages 180 to 189).

A few of the diagrams show negative areas, but these are confined to diagrams obtained on the lowest speed trials of the jacketed series. They do not occur with the unjacketed series, as, with jackets on, initial condensation is less, and the dryness-fraction at release is greater than without jackets. Less weight of steam is taken into the cylinders, and the release pressure is therefore lower than for the corresponding unjacketed trial. At the lowest speeds and pressure therefore the release pressure is atmospheric, and in one or two instances lower than atmospheric pressure. The negative area is so small as not to destroy the value of the trials and they have been included in the selected series.*

Saturation Curve.—From the condensed water measured from the exhaust a saturation curve has been plotted on each mean diagram representing the volume of the mean steam passing into the exhaust per stroke plus clearance steam. It has hitherto been usual to assume that this measured exhaust steam has actually passed through the cylinder, and that the difference between the expansion curve of the diagram and the saturation curve for the exhaust steam thus plotted represents condensation in the cylinder; but it is evident that any steam leaking through the slide-valve or piston to the exhaust will not be shown on the expansion curve of the indicator diagram, and that any other leakage through either piston or slide-valve will affect the

(*Continued on page* 190.)

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* The errors due to backlash and friction on an indicator pencil occur in opposite senses on the upward and downward stroke. When there is a negative area on an indicator diagram and the exhaust line cuts the expansion curve at any considerable distance from the end of the stroke, a small difference in the pressure at which this intersection occurs will make a large difference in the relative magnitudes of the positive and negative areas.

In such a case backlash and pencil friction will make the expansion curve too high and the exhaust line too low, so that these errors will have a double effect in falsifying the point of intersection. The resulting error in the nett area of the diagram is therefore out of all proportion to the corresponding error on a diagram where exhaust and expansion do not cut. In the present case the negative is so small a percentage of the whole area that the errors fall within the limits of accuracy obtainable with the remainder of the results.

Fig. 3.—*Mean Indicator Diagrams.*

Trials A_1, B_1, C_1, D_1.
Jacketed.

	Revs. per min. appro.	Mean Press.	I.H.P.	Steam Chest Press.	Press. at Inlet Valve.
				Lbs. Abs.	Lbs. Abs.
A_1	50	7·82	0·87	32·5	39·27
B_1	50	26·17	2·66	55·1	75·8
C_1	50	62·62	7·49	99·7	99·7
D_1	50	93·25	12·04	141	164·7

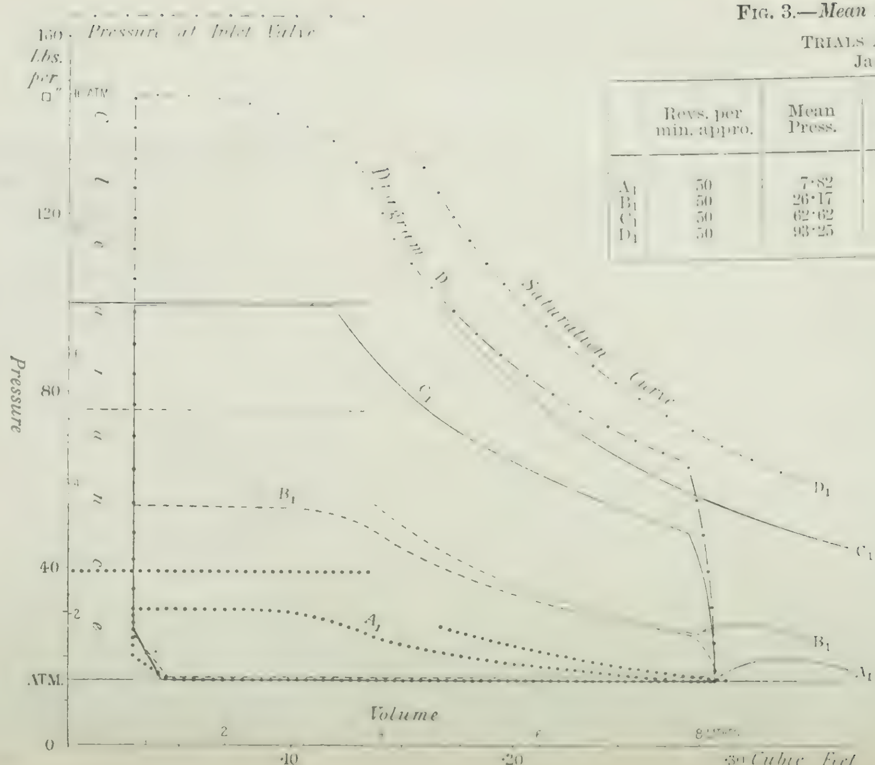


Fig. 4.—*Mean Indicator Diagrams.*

Trials AA_1, BB_1, CC_1, DD_1.
Unjacketed.

	Revs. per min. appro.	Mean Press.	I.H.P.	Steam Chest Press.	Press. at Inlet Valve.
				Lbs. Abs.	Lbs. Abs.
AA_1	50	13·04	1·53	37·6	51·5
BB_1	50	29·23	3·54	56	57·8
CC_1	50	61·93	7·24	99·4	105·2
DD_1	50	92·51	11·51	143·5	160·4

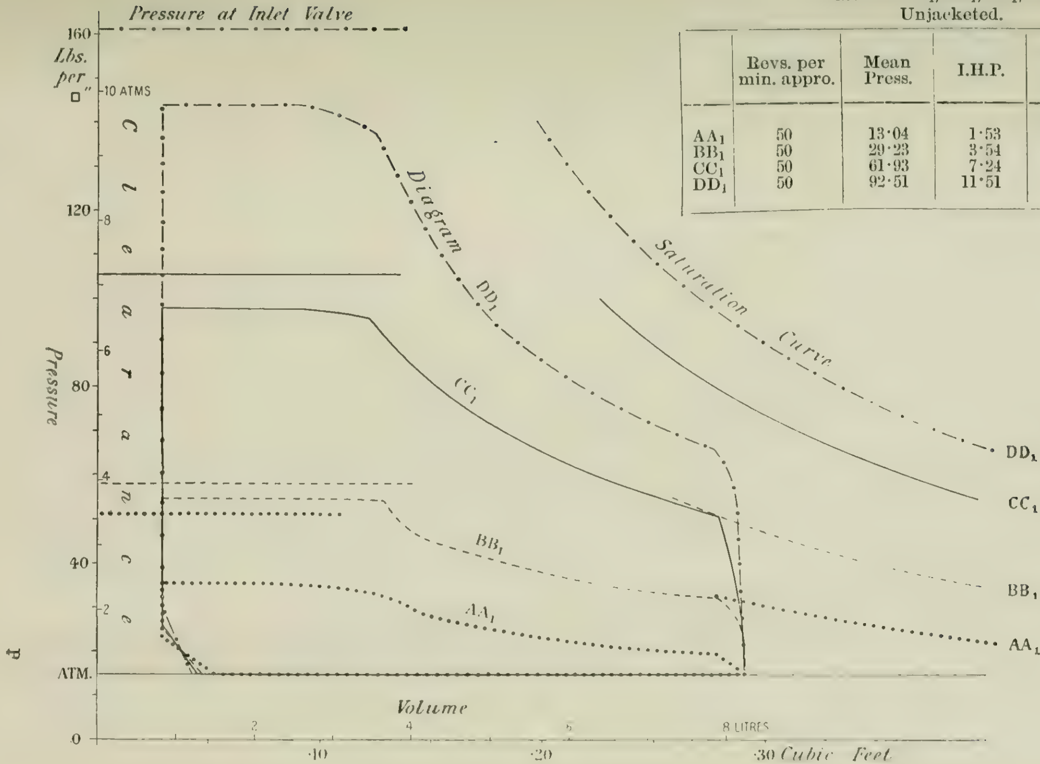


Fig. 5.—*Mean Indicator Diagrams.*

Trials A_2, B_2, C_2, D_2.
Jacketed.

	Revs. per Min. appro.	Mean Press.	I.H.P.	Steam Chest Press.	Press. at Inlet Valve.
				Lbs. Abs.	Lbs. Abs.
A_2	100	9·27	2·06	37	39·2
B_2	100	25·88	5·87	55	67·6
C_2	100	59·71	13·84	98·7	102
D_2	100	96·50	22·44	149·7	157·3

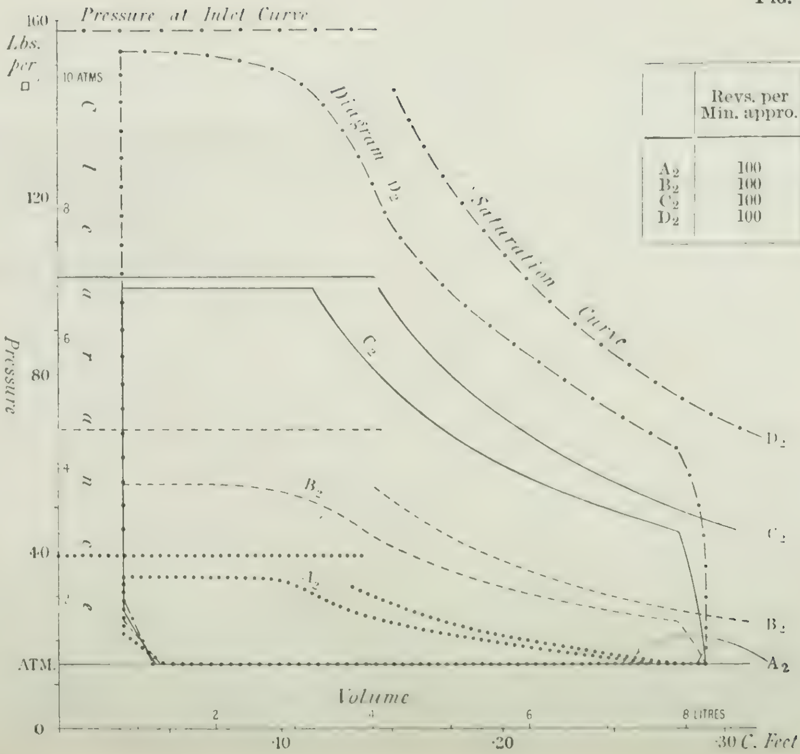


FIG. 6.—*Mean Indicator Diagrams.*

TRIALS AA_2, BB_2, CC_2, DD_2.
Unjacketed.

	Revs. per min. appro.	Mean Press.	I.H.P.	Steam Chest Press.	Press. at Inlet Valve.
				Lbs. Abs.	Lbs. Abs.
AA_2	100	12·36	3·00	35·7	49·5
BB_2	100	28·12	6·50	55·7	57·5
CC_2	100	55·04	12·35	90·25	93·7
DD_2	100	88·52	21·49	139·4	150·9

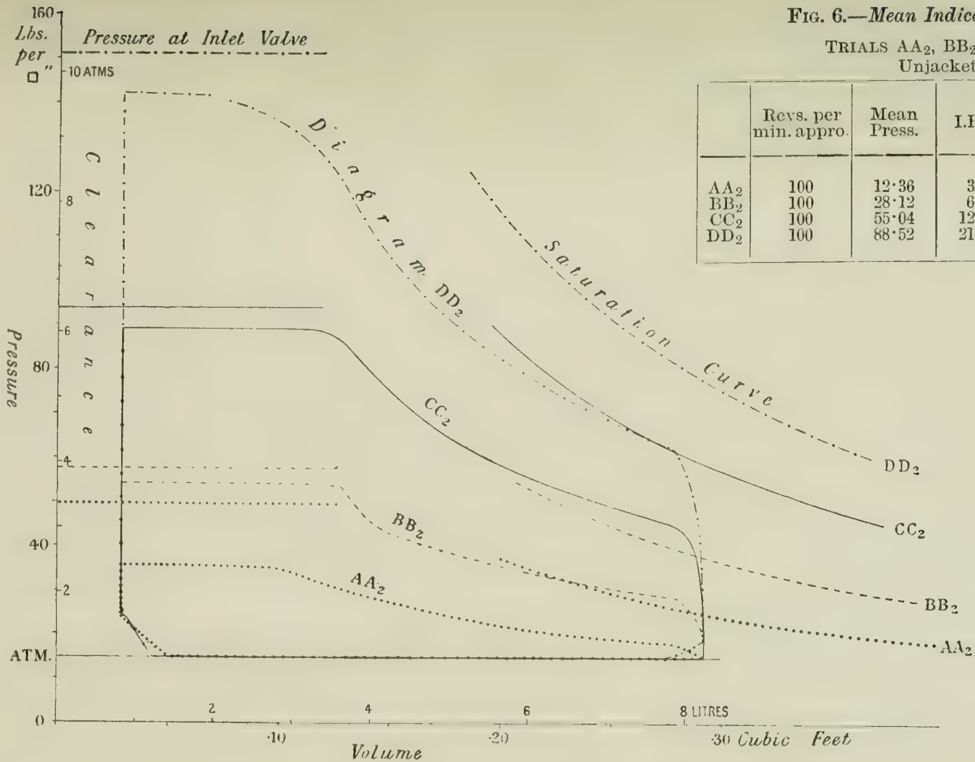
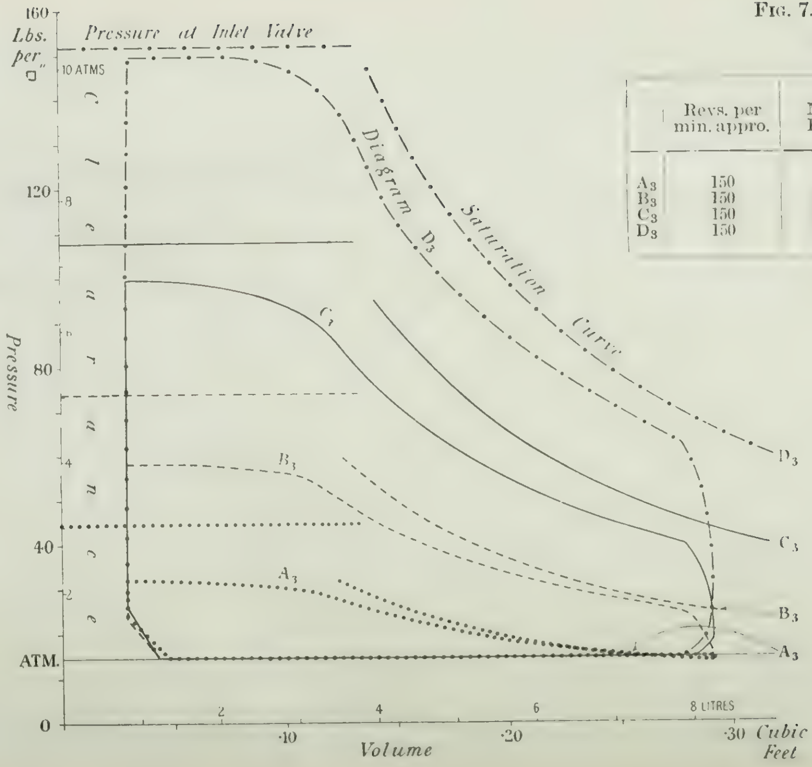


Fig. 7.—*Mean Indicator Diagrams.*

Trials A_3, B_3, C_3, D_3.
Jacketed.

	Revs. per min. appro.	Mean Press.	I.H.P.	Steam Chest Press.	Press. at Inlet Valve.
				Lbs. Abs.	Lbs. Abs.
A_3	150	8·23	2·86	31·05	44·7
B_3	150	27·11	9·39	56·74	74
C_3	150	55·38	19·63	93·9	107·7
D_3	150	94·80	31·14	146·5	151·5



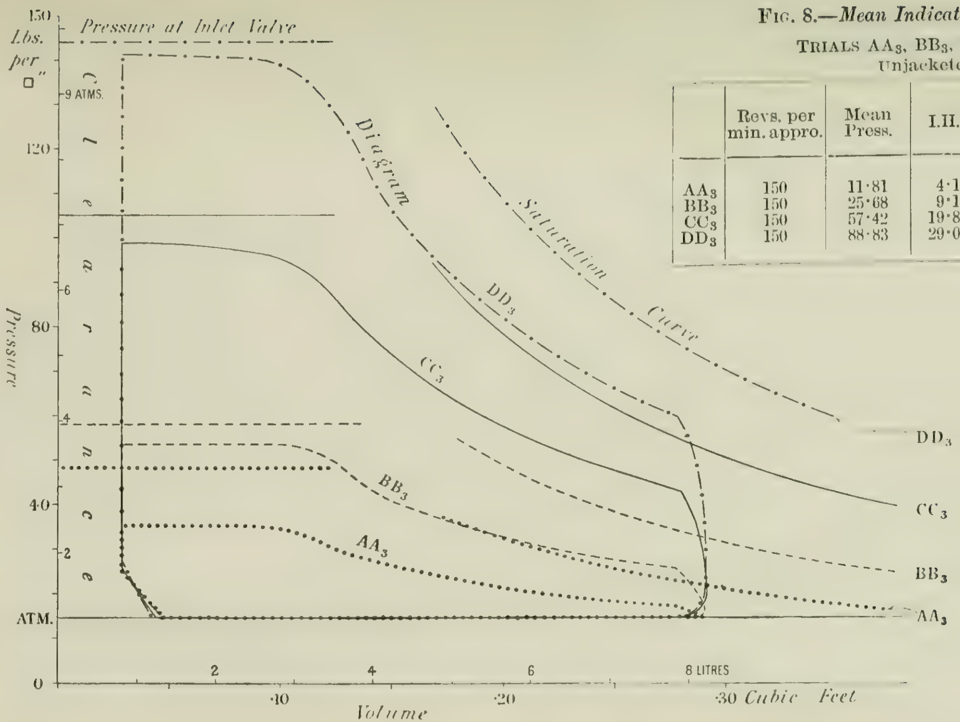


FIG. 8.—*Mean Indicator Diagrams.*

TRIALS AA_3, BB_3, CC_3, DD_3.
Unjacketed.

	Revs. per min. appro.	Mean Press.	I.H.P.	Steam Chest Press.	Press. at Inlet Valve.
				Lbs. Abs.	Lbs. Abs.
AA_3	150	11·81	4·10	36·7	48·4
BB_3	150	25·68	9·12	55	57·8
CC_3	150	57·42	19·80	98·2	105·2
DD_3	150	88·83	29·08	137·9	144·1

Fig. 9.—*Mean Indicator Diagrams.*

Trials A_4, B_4, C_4, D_4.
Jacketed.

	Revs. per min. appro.	Mean Press.	I.H.P.	Steam Chest Press.	Press. at Inlet Valve.
				Lbs. Abs.	Lbs. Abs.
A_4	200	9·6	4·45	33·2	47·1
B_4	200	23·52	10·93	54·44	69·14
C_4	200	55·3	25·25	96	101·7
D_4	200	85·9	38·10	139·3	157·5

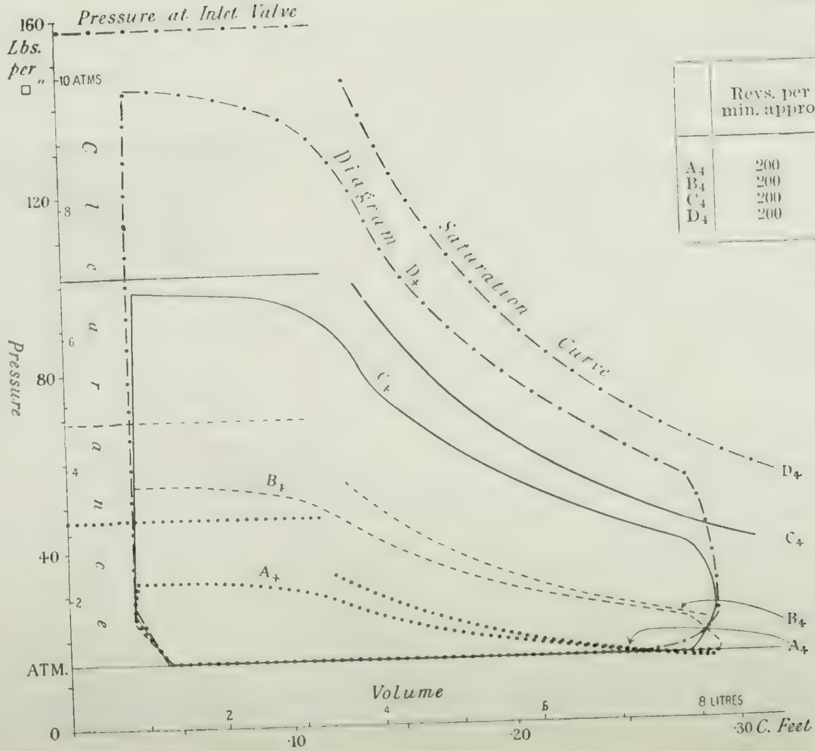


FIG. 10.—*Mean Indicator Diagrams.*

TRIALS AA_4, BB_4, CC_4, DD_4.
Unjacketed.

	Revs. per min. appro.	Mean Press.	I.H.P.	Steam Chest Press.	Press. at Inlet Valve.
				Lbs. Abs.	Lbs. Abs.
AA_4	200	13·22	5·93	40	59·7
BB_4	200	25·22	11·39	55	57·7
CC_4	200	52·08	22·20	88·6	90·9
DD_4	200	77·03	32·62	125·8	135·3

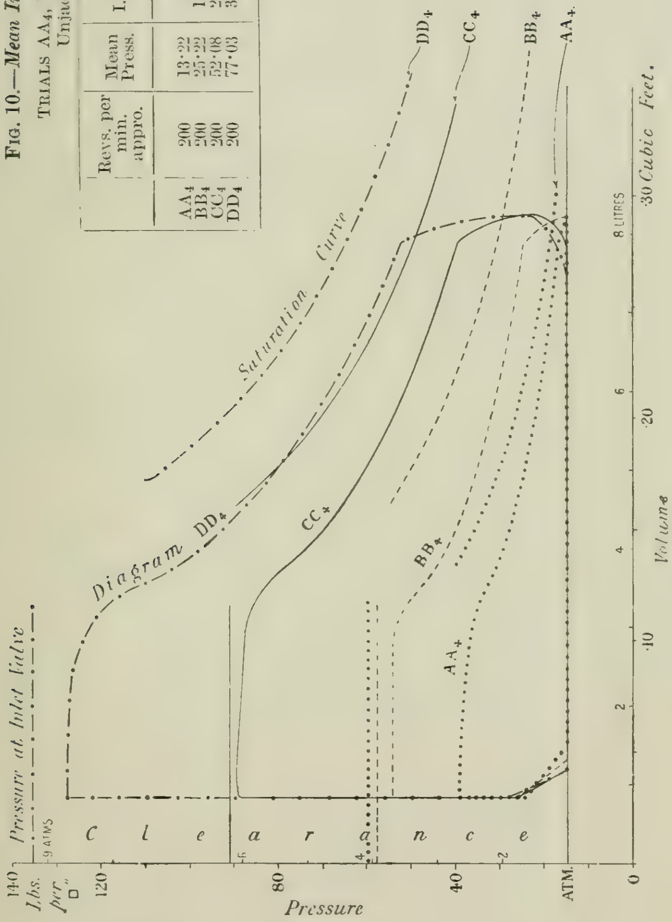


FIG. 11.—*Mean Indicator Diagrams.*

TRIALS A_5, B_5, C_5.
Jacketed.

	Revs. per min. appro.	Mean Press.	I.H.P.	Steam Chest Press.	Press. at Inlet Valve.
				Lbs. Abs.	Lbs. Abs.
A_5	250	11·35	6·77	35·5	44·2
B_5	250	26·75	14·67	56·4	66
C_5	250	46·8	26·82	84·5	92·7

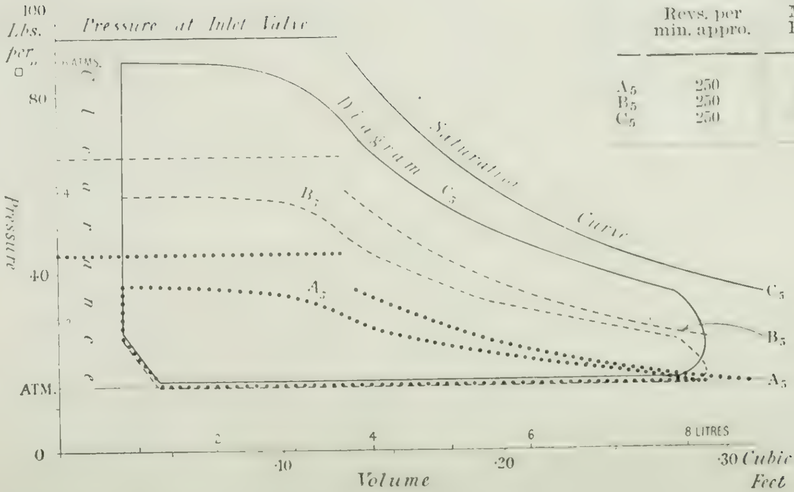


FIG. 12.—*Mean Indicator Diagrams.*

TRIALS AA_5, BB_5, CC_5.
Unjacketed.

	Revs. per min. appro.	Mean Press.	I.H.P.	Steam Chest Press.	Press. at Inlet Valve.
				Lbs. Abs.	Lbs. Abs.
AA_5	250	12·40	6·96	37	48·9
BB_5	250	25·07	15·01	54·2	61·7
CC_5	250	47·74	27·24	87·5	105·2

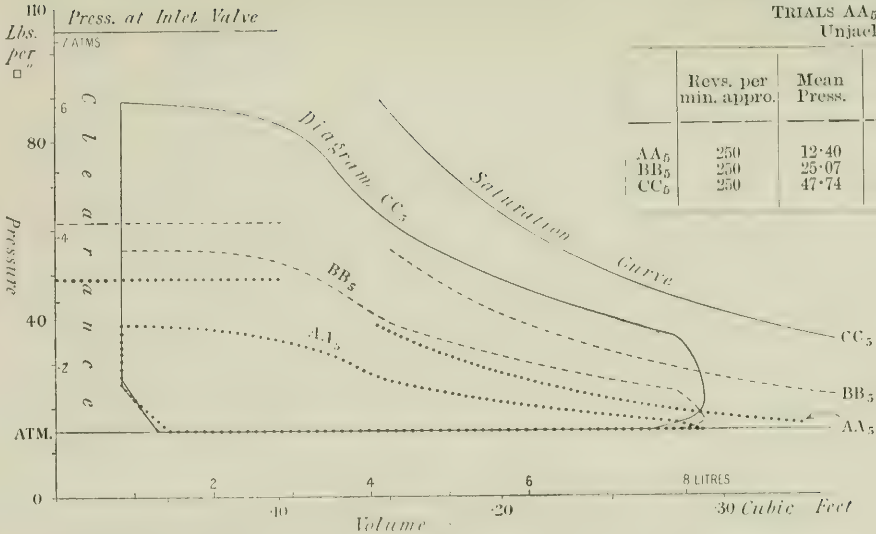


diagram so as to modify conclusions drawn without taking such leakage into account.

Messrs. Callendar and Nicolson* in their extremely suggestive Paper have shown that such leakage may be considerable, and in the present trials an attempt has been made to measure, analyse, and allow for the various leakages which occur. This analysis confirms the conclusions at which they arrived, that without such allowance no correct determination can be made of the relative weight of steam and moisture present in the cylinder.

Thermal Units used per H.P. Minute.—To calculate the thermal units per H.P. consumed by the engine, it has been assumed that the heat supplied to the engine is the difference between the heat units in the steam at the steam-chest pressure and temperature selected and the heat units in the condensed water. This is the same as assuming that the boiler and connections are outside the engine, and the losses in these external to it. The heat units calculated on this basis are given in cols. 19, 20 and 21, Table 13 (page 253); and col. 18, Table 14 (page 255).

In several trials, as already noted, the steam-valve was set so as to produce throttling and slight superheating at admission. The moisture in the steam entering the stop-valve was less than 2 per cent., and under these conditions the superheating cannot in any case have been greater than 4° F. In calculating the thermal units supplied to the engine the superheating calculated on this basis has in every case been taken into account.

Standard of Comparison.—The standard of comparison taken is the Rankine engine working between the extreme limits of temperature. The upper temperature for the standard Rankine engine has been taken as the temperature corresponding to the pressure in the steam-pipe on the boiler side, but close to the engine stop-valve.

The British thermal units required by a Rankine engine working between the above limits is given in col. 23, Table 13; and col. 19,

* The Proceedings, Institution of Civil Engineers, 1897–8, vol. cxxxi, page 147.

Table 14. The efficiency ratio or the ratio between the heat required by the Rankine engine and the heat required by the experimental engine has been calculated and is given in cols. 25 and 26, Table 13; and col. 21, Table 14.

For comparison with other records in which a Carnot engine has been taken as the standard of comparison, the heat units required per H.P. minute for a Carnot engine working between the same limits of temperature as the Rankine engine has been given in col. 24, Table 13; and col. 20, Table 14, and the efficiency ratio of the experimental engine to the Carnot engine is given in col. 27, Table 13; and col. 22, Table 14.

For each trial a temperature entropy diagram has been constructed, and the entropy diagrams for each temperature series and each speed series are shown superimposed upon one another in Figs. 13 to 30 (pages 192 to 207) so that a direct comparison can be made of the thermal units required at constant temperature and at constant speed and at each temperature and at each speed.

Leakage through Slide-valve.—There are two obvious methods of experimentally determining the leakage through the slide-valve. Either a special valve can be used with sufficient lap to cover the steam-port throughout the valve stroke or the steam-ports themselves can be blocked. In either case the leakage will be determined by admitting steam to the slide-chest, driving the engine by external power and measuring the steam escaping into the exhaust.

The first method involves a special slide-chest, and the steam-ports being open the leaking steam will emerge partly through the exhaust and partly through the cylinder. Errors will consequently result in the measurement of the leak owing to the large areas on which unmeasured condensed steam will be deposited. Moreover, if the leakage in the case of flat plates sliding on one another is affected by the width of surface in contact, the additional overlap of the special valve will affect the leakage and vitiate the comparison of the experimental results with the leakage

(*Continued on page* 208.)

FIG. 13.
Temperature Entropy Diagrams.

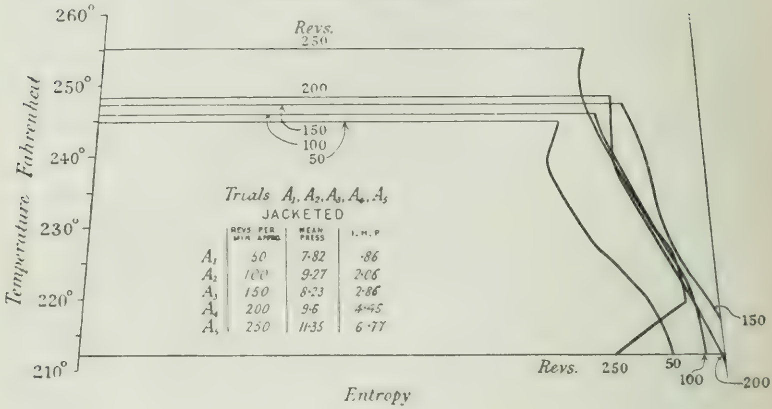


FIG. 15.
Temperature Entropy Diagrams.

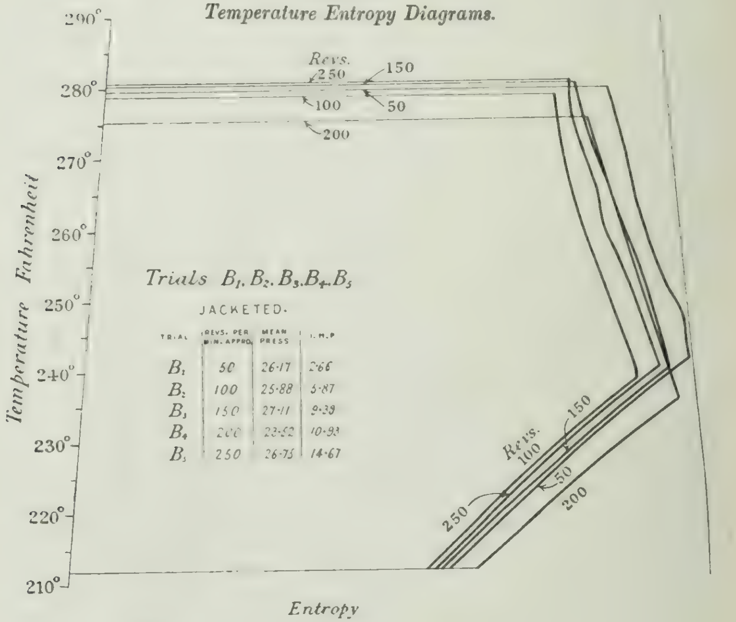


FIG. 14.
Temperature Entropy Diagrams.

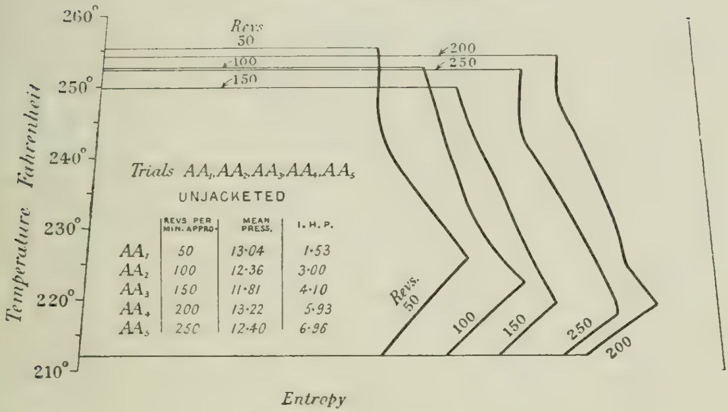


FIG. 16.
Temperature Entropy Diagrams.

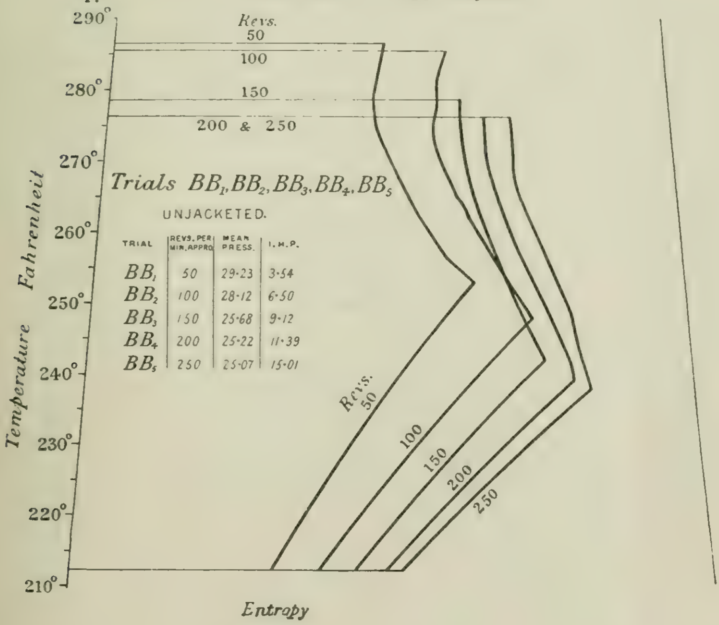


FIG. 17.

Temperature Entropy Diagrams.

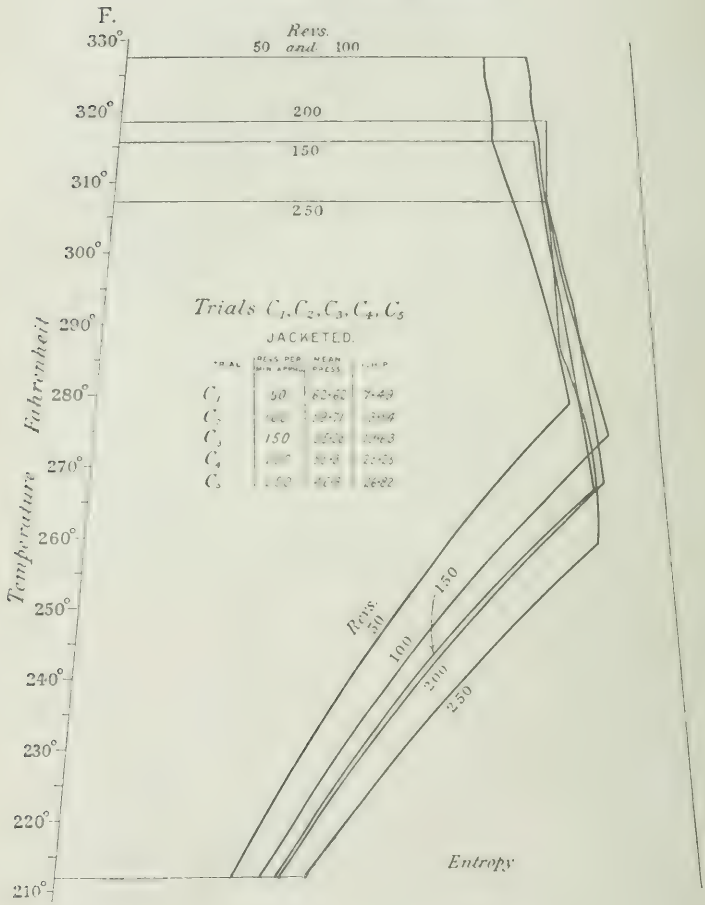


FIG. 18.

Temperature Entropy Diagrams.

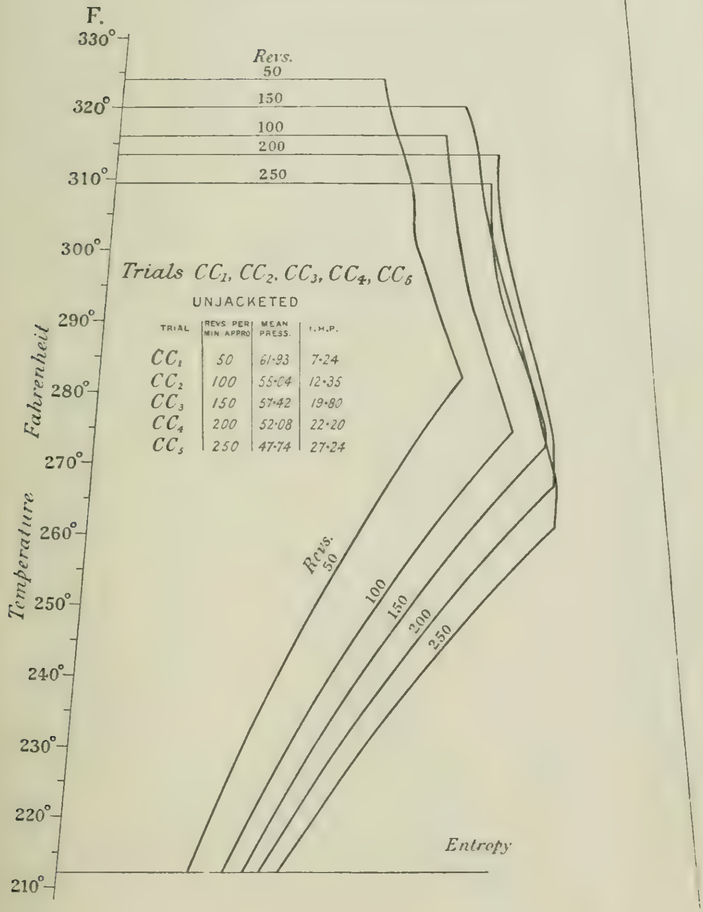


FIG. 19.

Temperature Entropy Diagrams.

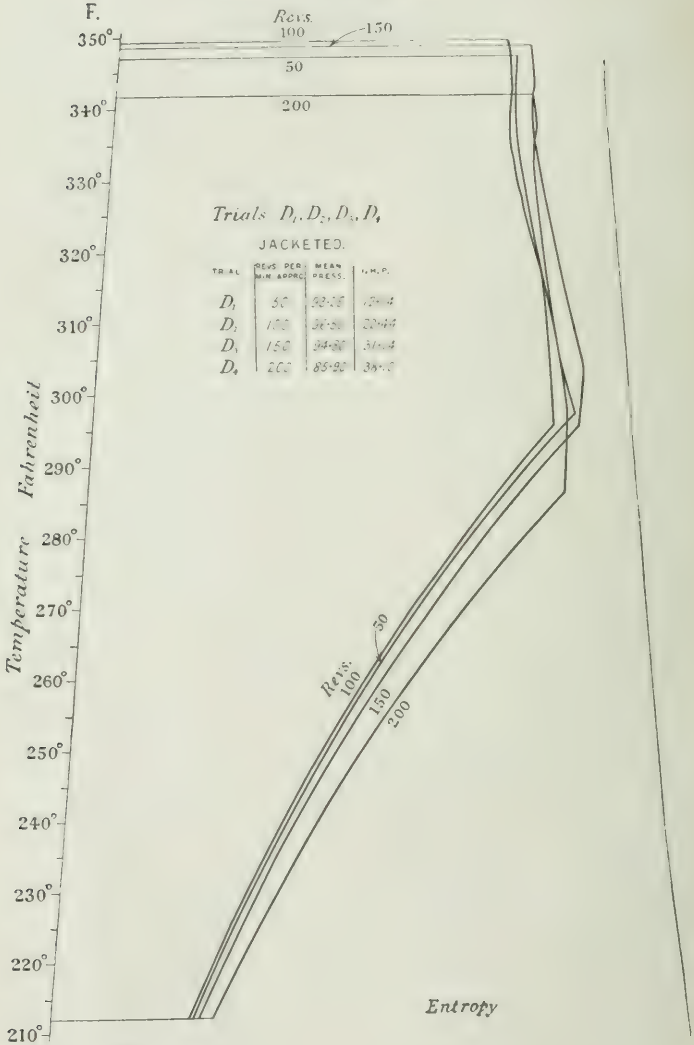
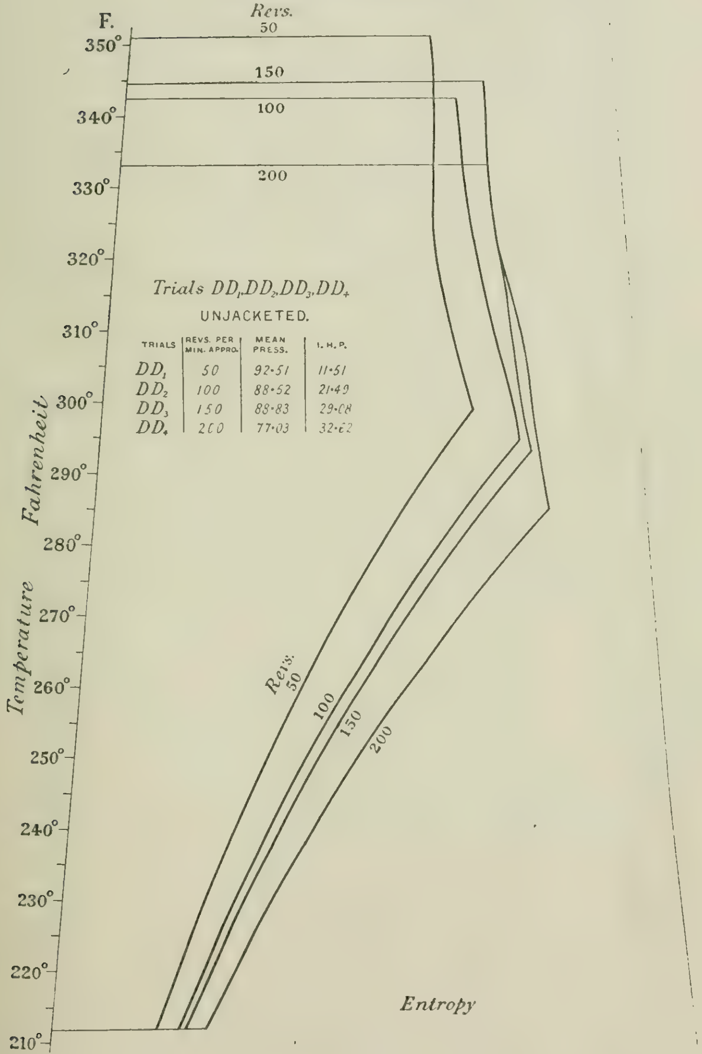


FIG. 20.

Temperature Entropy Diagrams.



TRIALS	REVS. PER MIN. APPRO.	MEAN PRESS.	I. H. P.
DD_1	50	92·51	11·51
DD_2	100	88·52	21·49
DD_3	150	88·83	29·08
DD_4	200	77·03	32·62

FIG. 21.

Temperature Entropy Diagrams.

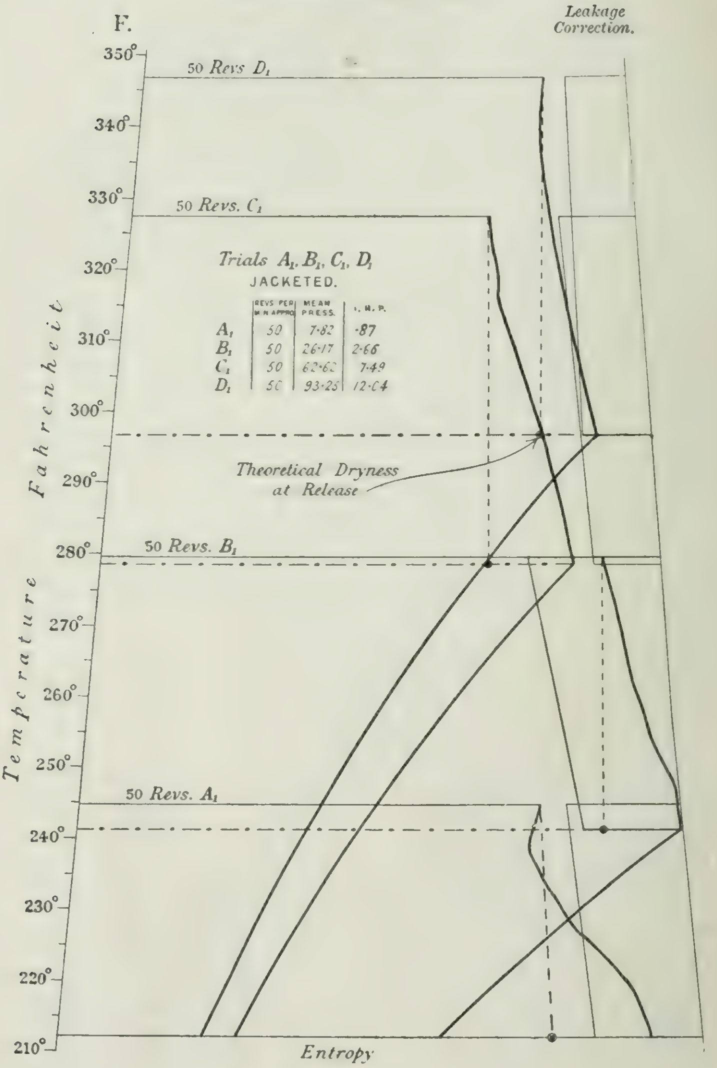


FIG. 22.

Temperature Entropy Diagrams.

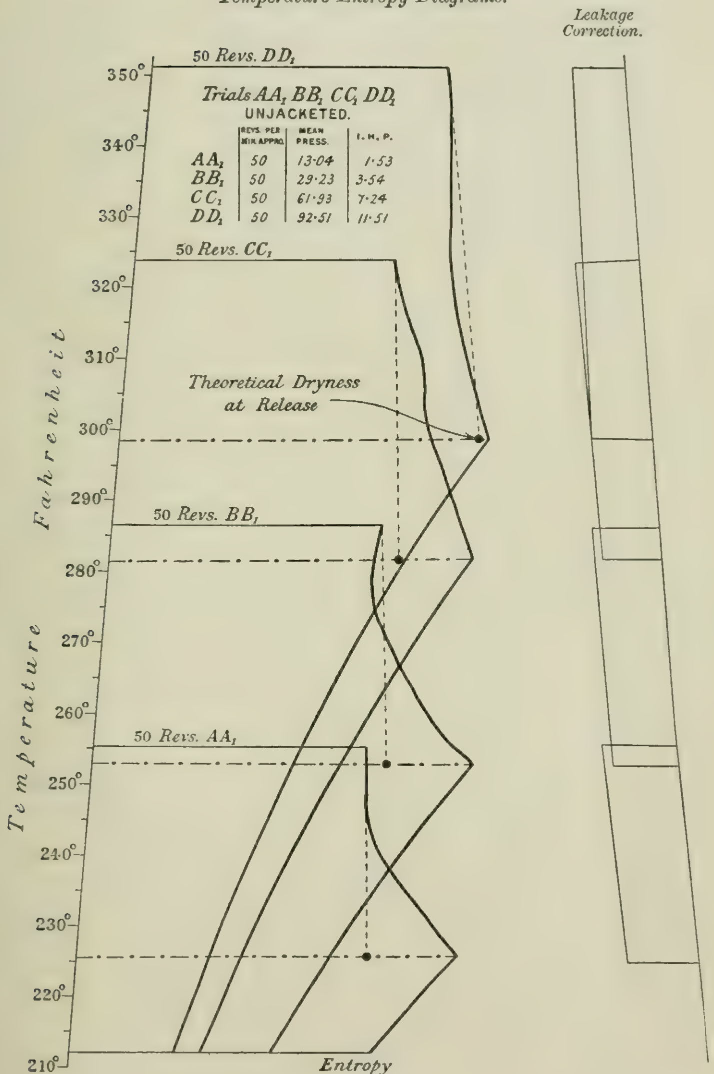


FIG. 23.

Temperature Entropy Diagrams.

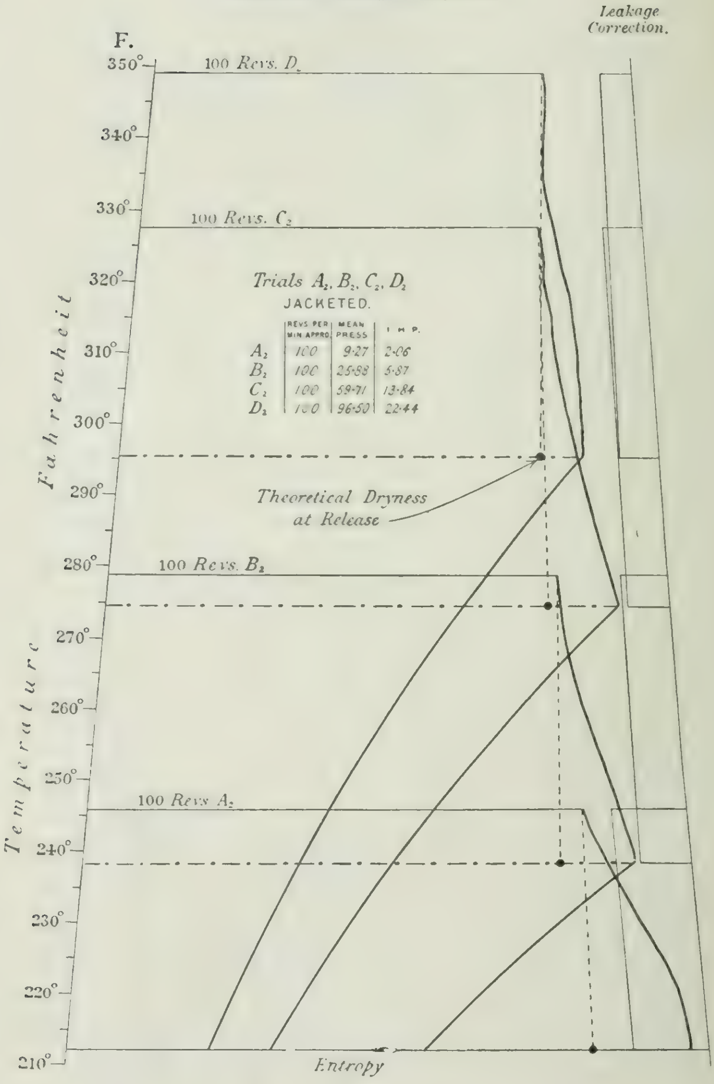


FIG. 24.

Temperature Entropy Diagrams.

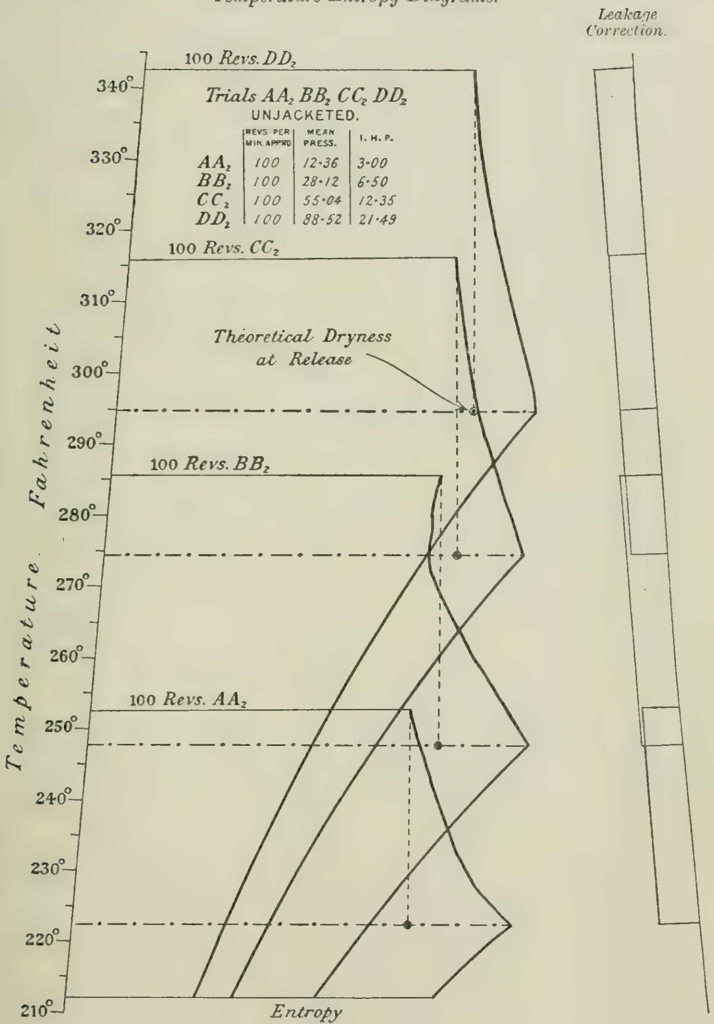


Fig. 25.

Temperature Entropy Diagrams.

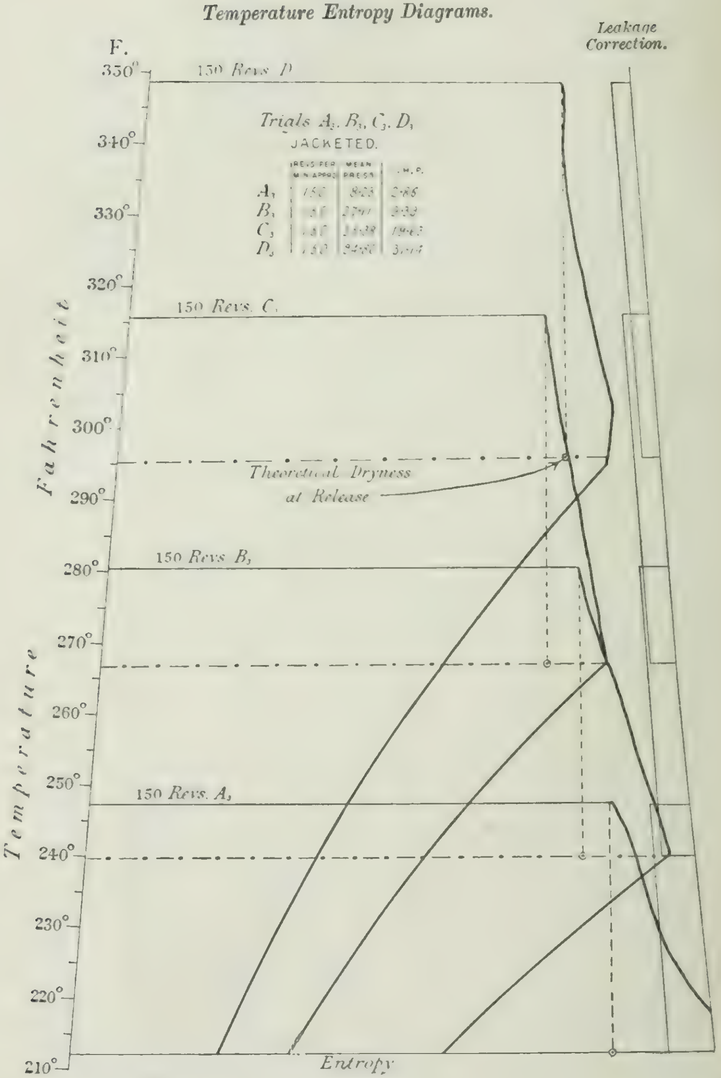


FIG. 26.

Temperature Entropy Diagrams.

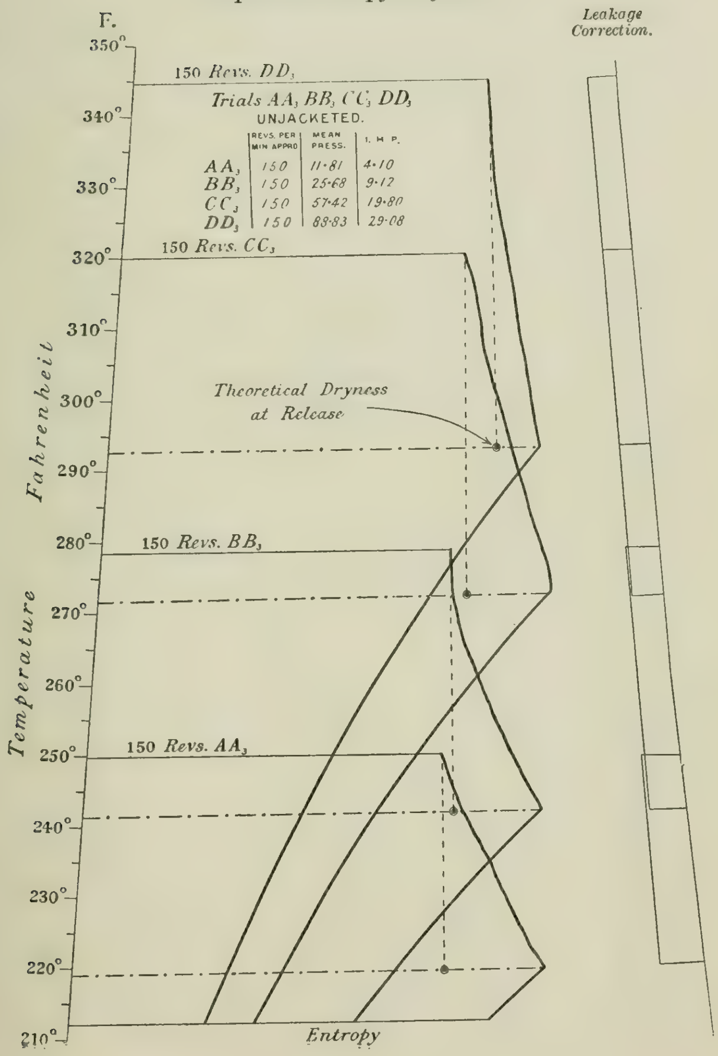


FIG. 27.

Temperature Entropy Diagrams.

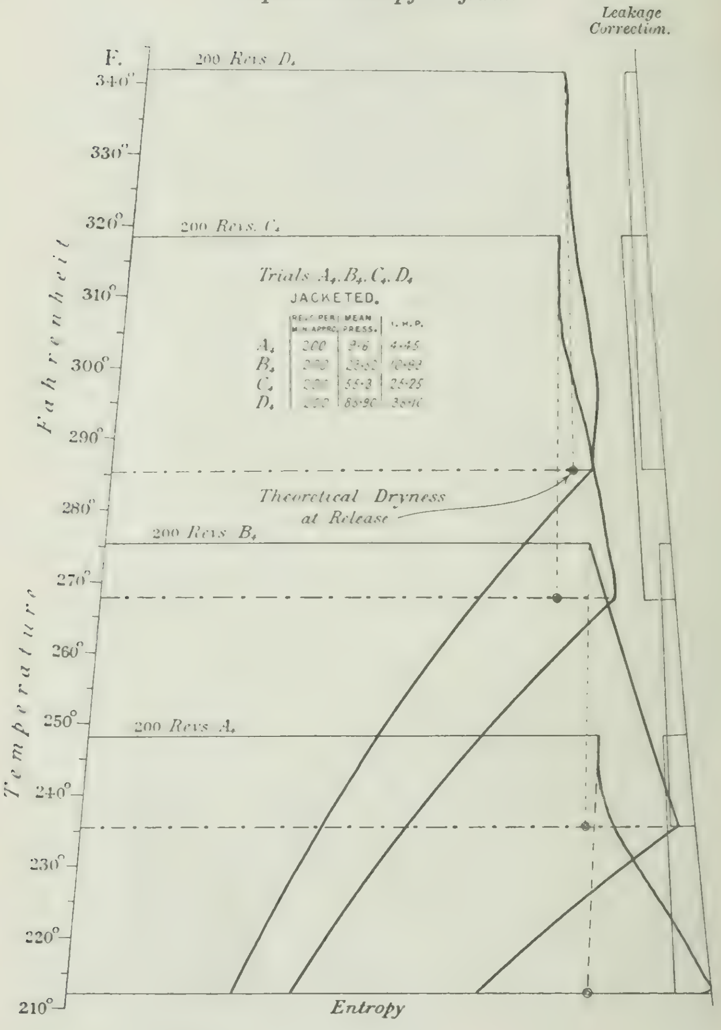


FIG. 28.

Temperature Entropy Diagrams.

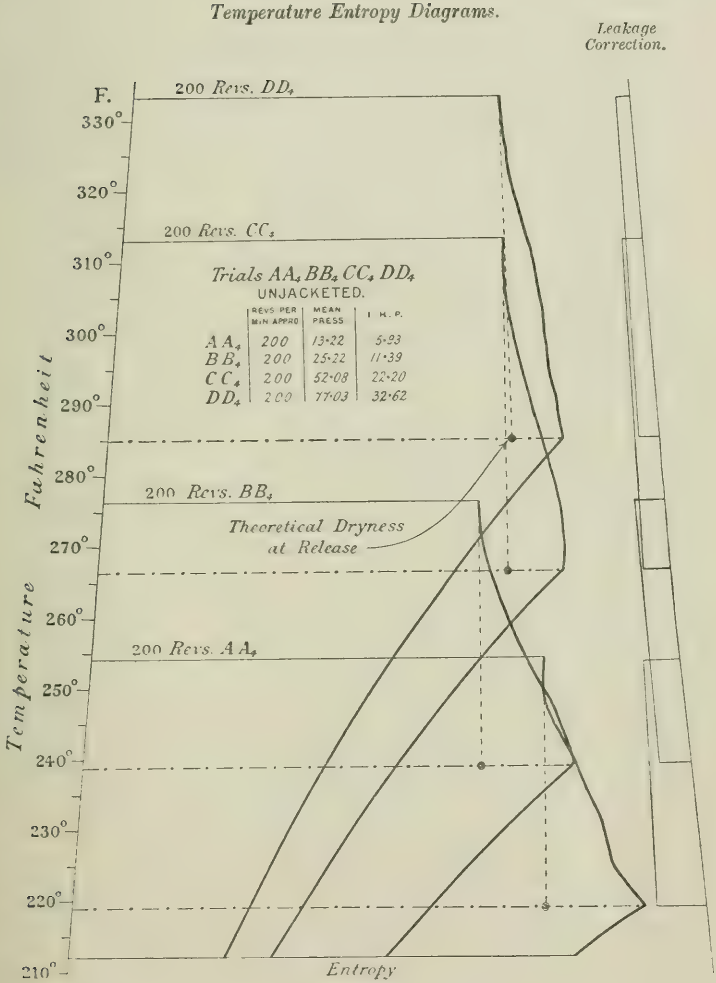


FIG. 29.

Temperature Entropy Diagrams.

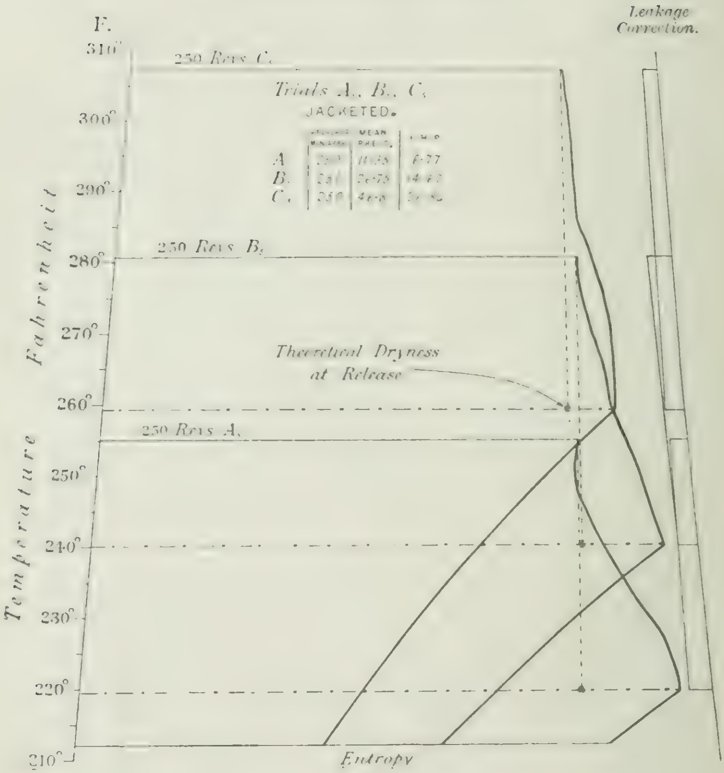
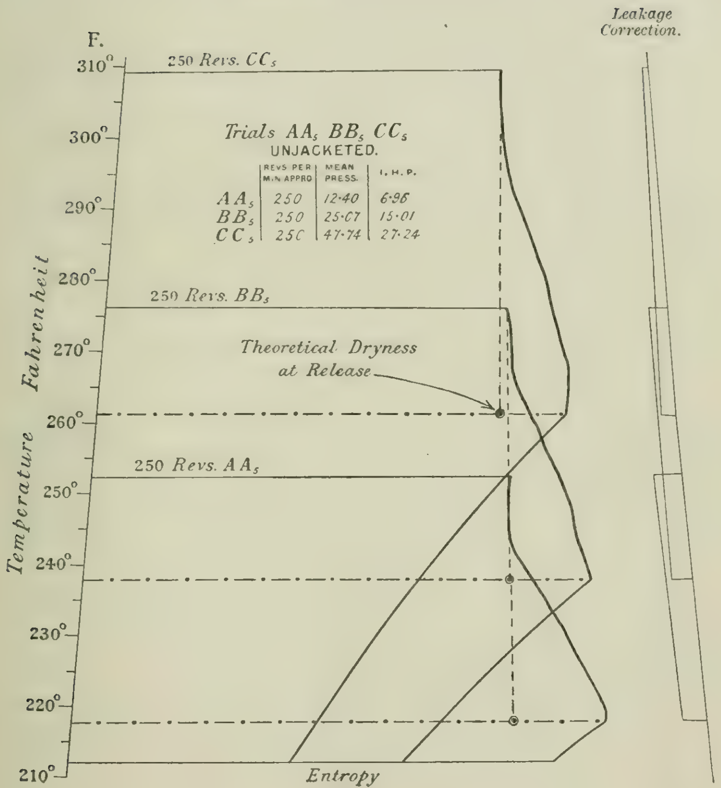


FIG. 30.

Temperature Entropy Diagrams.

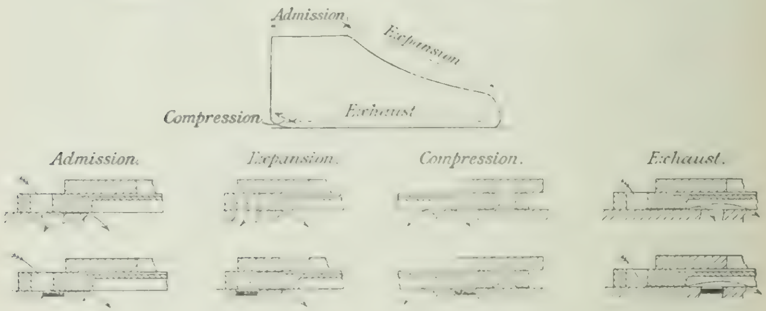


which obtains during the actual running of the engine under steam. Further, in actual working the steam-ports will, during admission and expansion, be full of steam at varying pressure, and leakage from the cylinder into the exhaust past the exhaust lap of the valve will take place in addition to the direct leak from the steam-chest to exhaust, while under experimental conditions with the special valve the cylinder will be always approximately at atmospheric pressure, so that leakage into the cylinder through the ports will be greater than under working conditions.

By the second method, namely, blocking the steam-ports and running with the normal working valve, the differences between

FIG. 31.

Four upper views show by arrows Leakage under Working Conditions.
,, lower ,, ,, ,, ,, ,, ,, Test ,,



experimental and working conditions are either eliminated or greatly reduced. Certain points of difference, however, will still remain, and the diagrams, Fig. 31, will help to explain these.

I. During admission *under working conditions* the flow of steam into the cylinder will to a certain extent check the tendency to leak from the steam-port past the valve into the exhaust.

With the blocked ports there will be no such check, and the leakage into the exhaust will therefore be slightly greater than under working conditions.

II. During expansion and also during compression *under working conditions* there will be leakage from the steam-chest past the lap into

the cylinder and from the cylinder past the valve into the exhaust. The amount of leakage into exhaust will therefore depend upon the difference between the expansion or compression pressure and the exhaust pressure.

With blocked ports there will be leakage past the lap into the clearance over the stop in the ports, and from that clearance, which will rapidly fill with steam at or about steam-chest pressure, to the exhaust.

The leakage into exhaust will therefore depend upon the difference between the steam-chest and the exhaust pressures, modified by the small amount of expansion which takes place in the clearances over the blocked ports. The leakage to the exhaust will therefore be greater with blocked ports than under working conditions.

Messrs. Callendar and Nicolson have pointed out that the leakage past the valve is most probably in the form of moisture condensed on the valve-face and re-evaporated, rather than a direct leakage of steam, and it will be seen that the leakage experiments detailed below confirm this conclusion. But this being the case, it is important to note that to imitate working conditions the cylinder walls, slide-face, and surrounding metal should be kept as near to the working conditions of temperature as possible. As the cylinder with blocked ports will not, as in working, be kept warm by the admission of steam at every stroke, the leakage found with both barrel and ends of cylinder jacketed has been accepted as the nearest approximation to the leakage taking place both in the jacketed and unjacketed series of trials.

The leakage trials described in the present Report were made on the high-pressure cylinder with the ordinary valve and with blocked ports, the engine being driven at the several trial speeds by external power and steam of the several trial pressures admitted to the steam-chest.

In blocking the steam-ports considerable difficulty was at first experienced, and numerous devices were tried before a steam-tight joint was obtained. The method ultimately adopted was to scrape a metal fitting piece flanged at each end to an absolutely tight fit in the ports, and then to screw this block down with a red-lead joint into recesses cut in the slide-face at each end of the port. This was found to give a tight joint.

TABLE 1.—*Pressures &c. during Measurements of Leakage past Slide-Valve with Steam-Ports Blocked.*
(*Results given in Table* 2.)

Average Pressures in lbs. per square inch absolute.				Differences in Pressure in lbs. per square inch.	
		Exhaust.		Steam-chest minus exhaust.	
Steam-pipe before inlet.	Steam-chest.	Engine standing, Valve in mid position.	Engine running at all speeds.	Engine standing, Valve in mid position.	Engine running.
39·25	35	—	16·25	—	18·75
50·5	45	15·5	16·75	29·5	28·25
66·25	63	15·75	17	47·25	46
96·25	93	15·75	18·25	77·25	74·75
152	145	17·75	19·75	127·25	125·25

N.B.—On all the above trials the sight feed lubricator was supplying oil to the steam-pipe at the rate of about two drops per minute.

(*Table* 1 *continued in Table* 2.)

TABLE 2.—*Leakage past Slide-Valve with Steam-Ports Blocked.*

Leakage in lbs. per hour through Slide-Valve.									
Syphon Lubricator on Steam-Chest stopped.						Syphon Lubricator on Steam-Chest supplying freely.			
Cylinder ends jacketed only.		Ends and Barrel of Cylinder Jacketed.							
Engine standing, Valve in mid position.	At 50 revs.	Engine standing, Valve in mid position.	At 50 revs.	At 156 revs.	At 252 revs.	Engine standing, Valve in mid position.	At 50 revs.	At 156 revs.	At 250 revs.
—	—	—	—	14·1	13·5	7·7	11·6	11·25	10·5
—	21·7	16·1	18·0	—	—	—	—	—	—
19·7	24·2	14·4	18·4	23·4	22·5	14·6	20·6	19·5	19·5
25·5	38·6	19·5	28·9	30·9	29·4	22·5	30·7	27·25	26·6
38·2	46·5	32·4	38·1	40·3	—	37·25	45·0	42·75	41·2

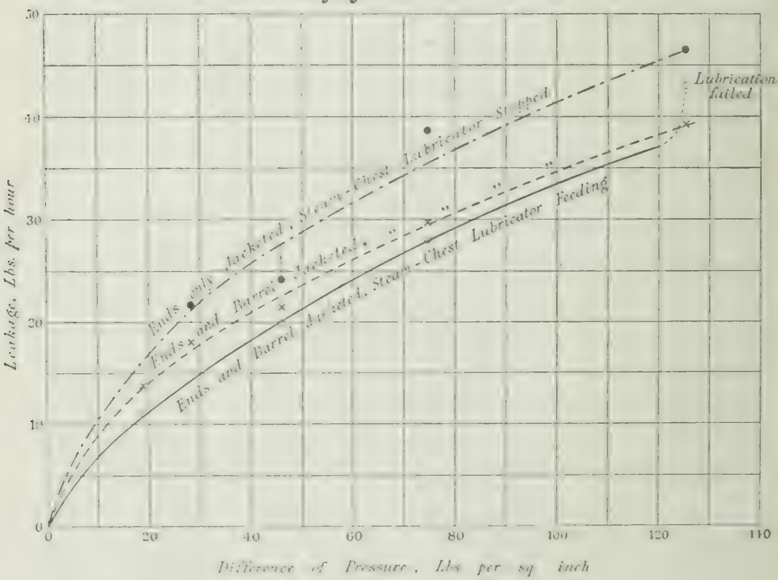
N.B.—On all the above trials the sight feed lubricator was supplying oil to the steam-pipe at the rate of about two drops per minute.

(*Table* 2, *continuation of Table* 1.)

The exhaust was connected to a condensing coil, so that all leakage into the exhaust could be measured with great accuracy. This arrangement was found to act admirably, but it was impossible to adjust this coil with such nicety as to prevent the escape of steam and at the same time to prevent some accumulation of pressure in the short exhaust branch. This back-pressure has been in every case recorded in Tables 1 and 2 (pages 210 and 211), which give the mean results for a number of concordant experiments measured under varying conditions.

FIG. 32.

Curves plotted from Values of Table 2, showing Slide-Valve Leakage varying with Pressure.



The mean values of the last three columns of Table 2 (page 211) have been plotted on Fig. 32, and have been used for the corrections for leakage which follow.

Effect of Warm and Cold Cylinder.—On analysing these results it will be seen that, under given conditions, the leakage when the barrel of the cylinder was warmed by the jacket was considerably less than

when it was cold. From what has previously been said, the proper correction to employ will be that obtained with the cylinder ends and barrel warmed.

Effect of Lubrication on Leakage.—In all except the 50-revolution trials there is a distinct reduction in leakage when the sliding surfaces are well lubricated, over the corresponding leakage with scant lubrication. This effect is not however so constant or so large as to warrant any definite quantitative analysis of the results. It is of course difficult to ensure uniformity in the lubrication of the surfaces, and the discrepancies are no doubt largely due to breaks in continuity of the oil film. The cases in which such a reduction was observed were however so numerous in individual trials as to definitely prove that, where the oil film is uniform and continuous, leakage is appreciably reduced. The curves on Fig. 32 show this clearly, although the reduction diminishes with increase of pressure. It is interesting to note on the curve for the well-lubricated jacketed trials that, where in one instance the lubrication failed, the leakage at once runs into and above the curve for scant lubrication.

Effect of Pressure on Leakage.—The leakage, as would be anticipated, rises with an increase of pressure between steam-chest and exhaust. Where the valve is stationary in mid position, the leakage increases approximately as the pressure. Where the engine is running, however, the leakage does not increase so rapidly as the pressure, and the higher the speed the larger does this divergence become. It is evident that this bears a striking resemblance to the laws governing condensation and re-evaporation on the cylinder walls of steam-engines, and when the amount of the leakage and its reduction by jacketing is considered the conclusion arrived at by Messrs. Callendar and Nicolson is irresistible, that much of the leakage must be in the form of moisture condensed on the valve face and re-evaporated as it passes over into the exhaust.

Effect of Wire-Drawing on Leakage.—As bearing upon the above point, experiments were made to determine what effect wire-

drawing, and therefore superheating the steam previously to its entering the steam-chest, has upon leakage. The following Table 3 shows the results obtained :—

TABLE 3.

Table showing the Effect upon Leakage through Slide-Valve of wire-drawing Steam at the Inlet-Valve. Lubrication on Steam-Chest flowing freely. All jackets on.

Condition of Trial.	Pressure, Lbs. per sq. in. absolute.					Leakage Lbs. per Hour.	Ratio. Leakage $\begin{cases}\text{Superheated}\\\text{Saturated.}\end{cases}$
	Steam-Pipe before Inlet.	Steam-Chest.	Exhaust.	Differences.			
				Steam-Pipe minus Chest.	Steam-Chest minus Exhaust.		
				Lbs.			
Engine standing, valve in mid position . . .	59·25	58·25	17	1	41·25	15·9	—
Engine standing, valve in mid position . . .	129·75	62·25	17	67·5	45·25	12·6	$\frac{12\cdot6}{15\cdot9} = 0\cdot8$
Engine running at 50 revs. . .	61·25	59·75	19	1·5	40·75	28·9	—
Engine running at 50 revs. . .	132	63	17·75	69	45·25	20·4	$\frac{20\cdot4}{28\cdot9} = 0\cdot7$

There is therefore a reduction of about 25 per cent. in the leakage, if wire-drawing to the above extent be resorted to.

Effect of Speed upon Leakage.—At the same pressure and under the same conditions of lubrication and jacketing, leakage

diminishes with increased speed of sliding. There is considerably less leakage when the engine and therefore the valve is stationary in mid position, but when the valve is moving there is appreciably less total leakage per hour when the engine is making 250 over the leakage at 50 double-strokes per minute. The leakage is consistently less at the high speeds than at the low where the cylinder walls are jacketed and the surfaces lubricated. This may partly be due to a more perfect spreading of the oil film at the higher speeds, or it may be due to the reduced time allowed for condensation and re-evaporation, or to a combination of the two. This clearly demonstrates that leakage was not in the present instance produced by the lifting of the valve in working, but by a more or less steady flow of moisture or steam between the valve and slide-face. The persistent and considerable difference between the leakage, when the engine is still with the valve in mid position and when it is running, points strongly to the conclusion that the amount of overlap and its variation has an important effect upon the leakage.

To elucidate this point, a series of leakage measurements were made with the engine standing at nine different positions of the crank, corresponding to nine successive positions of the valve during a revolution, the ports being blocked as before. The following Table 4 (page 216) gives the results of these measurements. They were made at the highest pressure of the boiler.

It is interesting to note that the mean value of the leakage at the nine positions is 45·95 lbs. per hour as compared with 45 lbs., the value obtained when running at 50 revolutions; also that at mid-position the mean of the two measurements is 36·9 lbs. per hour or practically the same as the mean of the values previously found.

Further, the variations in leakage occur with corresponding variations in the combined overlap at the two ends of the valve, the variations being very closely in the inverse ratio to the overlap. The following illustrations help to make this clear, Fig. 33 (page 217).

Analysis of Leakage and Method of applying Correction.—Assuming with Messrs. Callendar and Nicolson that the leakage varies as the perimeter round which escape from a higher to a lower pressure can take place, and to the difference of pressure, and inversely as the

TABLE 4.

Leakage past Slide-Valve, Engine standing at different Valve-Positions.

Position of Valve.	Position on Diagram, Fig. 33.	Steam pipe before inlet. Lbs. per sq. in.	Pressures absolute. Steam-chest. Lbs. per sq. in.	Pressures absolute. Exhaust. Lbs. per sq. in.	Difference Chest minus Exhaust. Lbs. per sq. in.	Leakage. Lbs. per hour.
Mid position . .	1	151	146	20·1	125·9	37·8
⅛th forward stroke of valve—crank at 45°	2	150·5	145·5	22	123·5	46·8
Front end full open to steam—crank 60° end of valve stroke .	3	150	144	23·2	120·8	47·6
Expansion valve at cut off—crank 90° .	4	151·5	145·75	21·25	124·5	56·4
During expansion (front end)—crank at 120°	5	151	145·25	20	125·25	46·8
Valve in mid position—crank 180° .	6	154	148·5	20	128·5	36
Back end full open—crank 240° . .	7	152	146	21	125	44
End of valve stroke, expansion valve at cut off—crank 270°	8	151·25	144·5	21·75	122·75	52·8
During expansion (back end)—crank 300° .	9	152	146	19	127	43·3

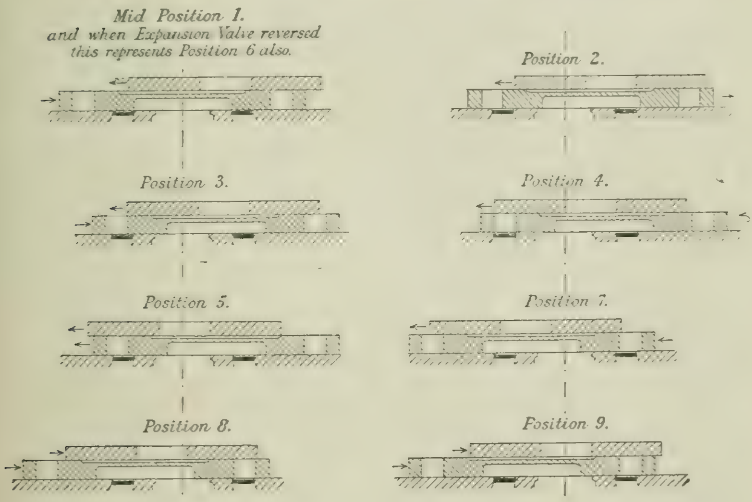
overlap of the valve over the ports, the measurement of the actual leakage under given conditions will enable the factor to be determined, by which that ratio must be multiplied to obtain the mean rate of leakage at any pressure. The present experiments show that the factor so found is not a constant.

The leakage is not directly proportional to the pressure for all speeds, and there is reason to doubt whether it is exactly inversely proportional to the overlap. But these assumptions are sufficiently accurate, if suitable values of the factor are introduced, to enable an approximate correction for leakage to be made by their aid.

The total leakage found with jacketed and lubricated surfaces and given in the latter columns of Table 2 (page 211) is, as already pointed out, larger than the leakage actually taking place in the

Fig. 33.

Diagrams showing position of Main and Expansion Slide-Valves at nine points of Stroke, referred to in Table 4.

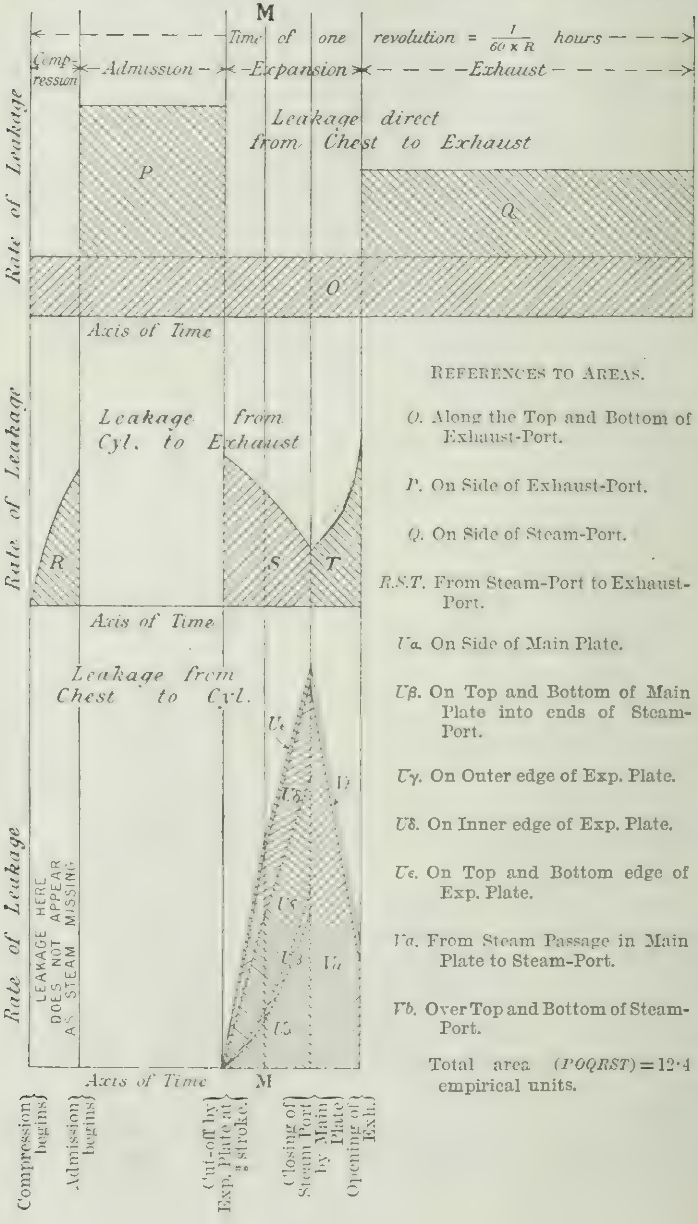


engine under working conditions. By the help of the following diagrams a fairly close estimation of the relative leakages under the two sets of conditions may be made.

Fig. 34 (page 218) represents on an empirical scale the leakage which will take place under working conditions, if the assumptions above are approximately true.

Fig. 35 (page 219) similarly represents the leakage with blocked steam-ports. Of the total leak about 76 per cent. appears to be leak

FIG. 34.—*Leakage through Slide-Valves. Probable Leaks during Working Stroke.*



REFERENCES TO AREAS.

O. Along the Top and Bottom of Exhaust-Port.

P. On Side of Exhaust-Port.

Q. On Side of Steam-Port.

R.S.T. From Steam-Port to Exhaust-Port.

$U\alpha$. On Side of Main Plate.

$U\beta$. On Top and Bottom of Main Plate into ends of Steam-Port.

$U\gamma$. On Outer edge of Exp. Plate.

$U\delta$. On Inner edge of Exp. Plate.

$U\epsilon$. On Top and Bottom edge of Exp. Plate.

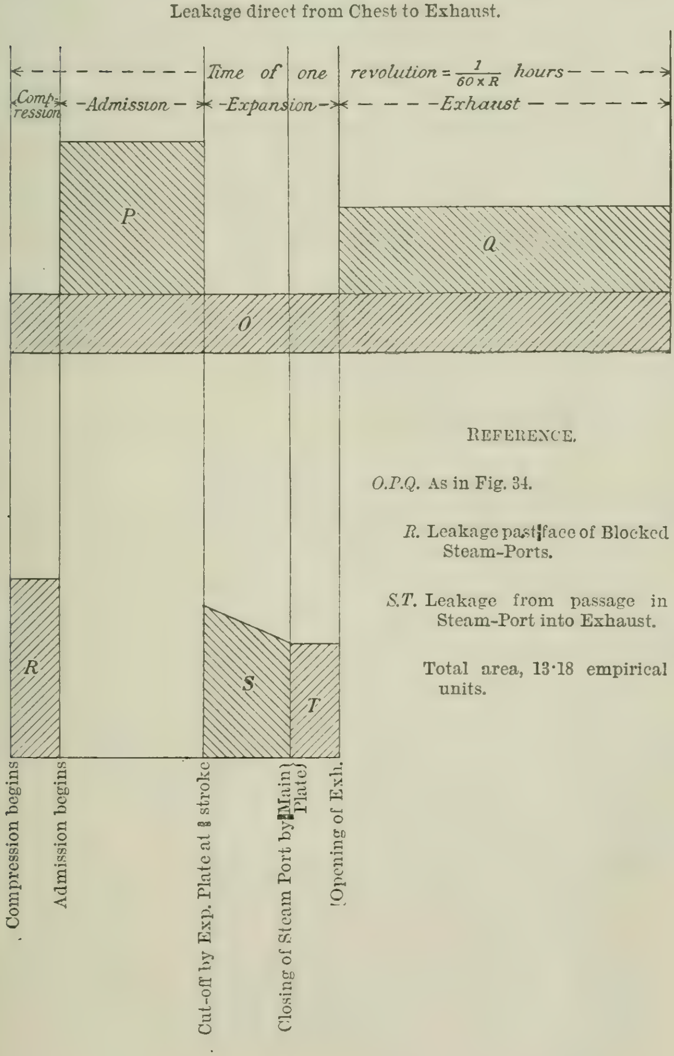
Va. From Steam Passage in Main Plate to Steam-Port.

Vb. Over Top and Bottom of Steam-Port.

Total area $(POQRST) = 12 \cdot 4$ empirical units.

FIG. 35.

Probable Leakage into Exhaust when running with Blocked Steam-Ports.



direct to the exhaust, and the remainder to be steam which passes into and out of the cylinder. This latter quantity therefore is apparent on, or absent from, the indicator diagrams according to the point of the stroke at which examination is made. The leakage into the cylinder during expansion appears to be about 22 per cent. of the total leak, and the leakage out of the cylinder during the same period about 10 per cent. of the total leak. The net leakage into the cylinder during the expansion period will therefore amount to about 12 per cent. of the total leakage.

In comparative units (*see* Fig. 34, page 218) the leakage to exhaust from both chest and cylinder equals $\frac{12 \cdot 4}{13 \cdot 18}$ of the corresponding values on Fig. 35. Therefore the total leakage up to release under actual working conditions will be about $0 \cdot 95$ times the leakage measured under test conditions. This quantity should therefore be deducted from the total measured exhaust before the weight of steam actually present in the cylinder up to release will be known.

To determine similarly the weight of steam present in the cylinder up to cut-off, from the total measured exhaust must be deducted all the steam which leaks into the exhaust from the chest, together with all the steam which leaks into the cylinder, after cut-off. That is, on Fig. 34, the areas $O + P + Q + R + U + V$ ($14 \cdot 34$ in comparative units); so that up to cut-off the steam to be deducted from the total measured exhaust, in order to determine the steam which is in the cylinder at cut-off, will be $\frac{14 \cdot 34}{13 \cdot 18} = 1 \cdot 1$ times the total measured leak with steam-ports blocked. These values have been employed in determining the corrected dryness-fractions given in Table 8 (page 228).

It will be interesting to determine the value of the factor C by which $\frac{\text{Difference of pressure} \times \text{perimeter}}{\text{Mean overlap}}$ should be multiplied in order to give the mean rate of leakage, and so to compare with the corresponding values found by Messrs. Callendar and Nicolson. The perimeter measured to the mean overlap round the steam-port and on the side and ends of the exhaust-port for one end of the slide-valve for the

valve of the experimental engine is 22·5 inches—the mean overlap is 1 inch.* The mean value of $\frac{\text{overlap}}{\text{perimeter}}$ is therefore 0·045. Taking mean values of the leakage as plotted on Fig. 32 (page 212), the value of the factor C will be as follows:—

TABLE 5.

Pressure in Chest. Lbs. per sq. in. absolute.	Difference of Pressure. Chest minus Exhaust in lbs.	Syphon Lubricator on Steam-Chest stopped.	Syphon Lubricator on Steam-Chest running freely.
35	18·75	0·032	0·026
63	46	0·022	0·019
93	74·75	0·018	0·016
145	125·25	0·0142	0·0145
Averages .	. . .	0·0215	0·019

As before stated, C is not a constant for the range of pressures experimented upon, although its mean value (namely, 0·02) is identical with the value found by Messrs. Callendar and Nicolson.

As already stated, its variation is probably due to the approximate character of the assumptions above made.

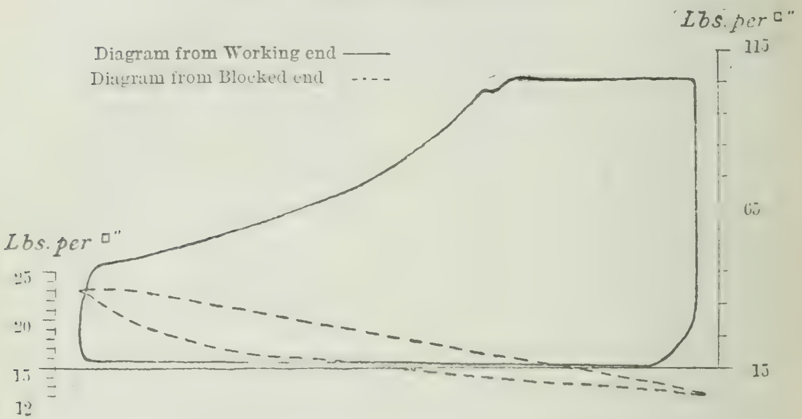
Percentage of Leakage to Steam passing through Cylinders.—If Tables 1, 2, 13 and 14 (pages 210, 211, and 252–255) be compared, it will be seen that the leakage, under given conditions of pressure, is equal to a maximum of 20 per cent. of the total steam used on the A_1 trial down to a minimum of 4 per cent. of the total steam used on the DD_4 trial. It is therefore in no case negligible.

Piston Leakage.—The leakage through the piston was measured by blocking the port at one end of the cylinder and running the engine single-acting. Cards of the working and blocked ends were

* For dimensions of valves and ports, *see* Appendix II (page 258).

also taken. One of these is shown on Fig. 36. It was found that the piston leak was independent of revolutions per minute, and was proportionate to the admission pressure and area of indicator diagram on the working side of the piston. The piston leak was found at its worst to be less than 2 per cent. of the steam consumption of the engine.

FIG. 36.—*Diagram showing Piston Leak.*



SERIES I.—JACKETED TRIALS.

In the jacketed series the barrels and both ends of the cylinders were jacketed with steam at boiler pressure, the discharge from the jackets being collected and measured.

Analysis of Results.—Table 13 (pages 252 and 253) shows the records obtained on the nineteen jacketed trials. At the highest pressure and greatest speed it was found impossible to obtain a consistent satisfactory trial, owing to the limits of the boiler used for the trial being reached. After a number of attempts therefore all the trials under these conditions being found to be unsatisfactory were discarded.

On a detailed examination of the records the following points are noteworthy :—

1. *Indicator Diagrams.*—(a) Admission line. For the series of trials at the lowest admission temperature, it was found necessary, as already mentioned, to raise the boiler pressure above that required in the cylinder so as to give a margin for driving the feed-pumps. In this series therefore the inlet-valve was used as a reducing valve, and this is clearly shown on the indicator diagrams by the considerable drop which there is between the pressure at the boiler side of the inlet-valve and the admission pressure on the diagrams. The wire-drawing resulting from this use of the valve caused superheating in some of the trials of this series.

The maximum difference between the pressure of the boiler side of the inlet valve and the steam-chest pressure occurring on the A_4 trial at 200 revolutions per minute, when a reduction from 47·1 to 33·2 lbs. per square inch was recorded, corresponding to a drop in temperature of 21·2° F., and on the B_1 trial where the pressures were 75·8 and 55·1 respectively, corresponding to a drop in temperature of 21° F., and the D_1 trial with a pressure before the inlet valve of 164·7 lbs. and in the steam-chest of 141 lbs. corresponding to a drop in temperature of 13° F. The minimum recorded difference was on the A_2 trial at 100 revolutions per minute, the pressures being 39·2 and 37 lbs. per square inch, giving a difference of 3° F. only. With the single exception of the B_1 trial, there was in no case superheating at cut-off.

(b) *Expansion Line.*—As the ratio of expansion was kept constant for the whole of the trials, the release pressure increased concurrently with the admission pressure. The constant volume rejection to exhaust therefore represents a larger and larger proportion of the whole range of pressures as the admission pressure rises. This is due to the fact that the ratio of expansion necessary for the lower pressure trials is not the most economical for the higher pressure trials. On the other hand, the high temperature at release on the higher pressure trials must ensure a temperature for the cylinder walls and end and piston surfaces, and probably throughout the exhaust, higher than in the low-pressure trials. The surface temperature and the critical dry temperature of the walls and surfaces therefore will be higher the higher the temperature of admission.

TABLE 6.

Jacketed Trials.

Range of Temperature.

Trial.	Initial Pressure.	Release Pressure.	Initial Temperature.	Release Temperature.	Difference.	Difference between Temperature at Release and 212° F.	Difference between Initial Temperature and 212° F.
	Lbs. per sq. in. abs.		F.°	F.°	F.°		
A_1	31	15	252	212	40	0	40
B_1	44	25	285	239	46	27	73
C_1	99	49	327	279	48	67	115
D_1	147	64	356	296	60	84	144
A_2	35	15	259	212	47	0	47
B_2	56	24·5	288	238	50	26	76
C_2	100	45	327	274	53	62	115
D_2	153	63	360	295	65	83	148
A_3	32·5	15·75	251	209	45	—3	42
B_3	59	24·5	291	238	53	26	79
C_3	100	40	327	267	60	55	115
D_3	140	63	358	295	63	83	146
A_4	33	15·75	255	209	46	—3	43
B_4	55	23	287	235	52	23	75
C_4	99	40	327	267	60	55	115
D_4	145	55	355	287	68	75	143
A_5	37·5	17	263	219	51	7	51
B_5	57·5	24·5	289	238	51	26	77
C_5	88	35	318	259	59	47	106

The trials have been arranged in order of speeds.

Table 6 (page 224) will help in comparing the trials from this point of view.

In it are given the admission and release temperatures, the range of temperatures between admission and release, and the range of temperatures between admission and exhaust, for the whole of the jacketed trials.

Exhaust and Compression.—With regard to the exhaust and compression portions of the stroke little need be said, as these are practically uniform for the whole series of trials.

Series II.—Unjacketed Trials.

In this series, of which detailed results are given in Table 14 (pages 254 and 255), the indicator diagrams show much the same features as have been noticed on the jacketed series. The reduction of pressure through the inlet valve was in general more on the unjacketed than on the jacketed series. The maximum drop on any of the trials occurred in the AA series. On the AA_4 trial at 200 revolutions, the difference between the inlet-valve pressure and the admission pressure was 19·7 lbs., corresponding to a difference of temperature of 25·6° F. On the AA_5 trial at 250 revolutions, at which the pressure at the boiler side of the inlet valve was 48·9, the pressure at admission was 37, corresponding to a difference in temperature of 17·3° F. The effect of wire-drawing through the valve is not apparent on the admission line of the lower speed trials; but, as the speed increases, the admission from being practically a straight line parallel to the base slopes down considerably, and at the same time the cut-off becomes more and more rounded instead of being sharp and distinct.

The only other trials upon which any considerable reduction occurred between the pressure at the back of the inlet valve and admission pressure were at the highest speeds of the CC (that is, the 315° F. unjacketed) and DD (that is, the 350° F. unjacketed) series. On the CC_3 trial, namely the trial at 150 revolutions and 315° F., there was a drop of 7 lbs. pressure and 5° F. in temperature

between steam-pipe and admission. On the DD_1 trial, that is, the trial at 50 revolutions, 350° F., the corresponding pressures (page 254) were 160·4 in the steam-pipe and 143·5 in the steam-chest, a drop of 16·9 lbs. pressure and 9° F. in temperature. This is the trial showing the maximum difference in the DD series.

Expansion.—With a constant ratio of expansion and varying initial pressure and speeds the same effect is produced, as was noticed in the jacketed trials.

Table 7 (page 227) gives the temperature ranges and difference for the unjacketed trials.

COMPARISON OF JACKETED AND UNJACKETED SERIES.

Condensation during Admission and re-evaporation during Expansion.—Table 8 (page 228), Columns 1 and 2 give the dryness-fractions for the whole of the trials for both series measured in the usual way, as the ratio between the steam measured upon the indicator cards up to cut-off and release and the measured condensed discharge from the exhaust and including clearance in each case. As before stated, the measured condenser discharge, including as it does all leakage, will not give a true measure of the weight of steam and moisture in the cylinder at cut-off. If the leakage for the known conditions of each trial be taken from the leakage curve, a new ratio can be found by calculation from the leakage area diagram which will represent the real dryness-fraction, for the steam actually present in the cylinder at cut-off. The values of this actual dryness-fraction for each trial are given in Columns 3 and 4 of Table 8. It will be seen that the leakage correction thus applied materially affects the estimate of condensation during admission. Similarly, the dryness-fraction at release, measured in the usual way as a fraction of the condensed exhaust plus clearance, is given in Column 2, while its true ratio, after allowing for leakage, is given in Column 4 of the same Table.

To show the re-evaporation during expansion, Columns 5 and 6 have been added. The former gives the percentage of the whole weight of mixed steam and water which would have been present

TABLE 7.

Unjacketed Trials.

Range of Temperature.

Trial.	Admission Pressure.	Release Pressure.	Admission Temperature.	Release Temperature.	Difference.	Difference between Temperature at Release and 212° F.	Difference between Initial Temperature and 212° F.
	Lbs. per sq. in. abs.		F.°	F.°	F.°		
AA_1	38	19	263	224	39	12	51
BB_1	55	32	286	253	33	41	74
CC_1	98	50	326	280	46	68	114
DD_1	143	66	354	298	56	86	142
AA_2	36	18	260	221	39	9	48
BB_2	55	29	286	247	39	35	74
CC_2	90	45	320	274	46	62	108
DD_2	142	62	354	294	60	82	142
AA_3	36	17·5	260	220	40	8	48
BB_3	54	26	285	242	43	30	73
CC_3	99	43	327	271	56	59	115
DD_3	141	60	353	292	61	80	141
AA_4	39	17·5	265	220	45	8	53
BB_4	54	25	285	239	46	27	73
CC_4	90	40	320	267	53	55	108
DD_4	128	53	346	284	62	72	134
AA_5	39	17	265	218	47	6	53
BB_5	56	24	288	237	51	25	76
CC_5	89	36	319	260	59	48	107

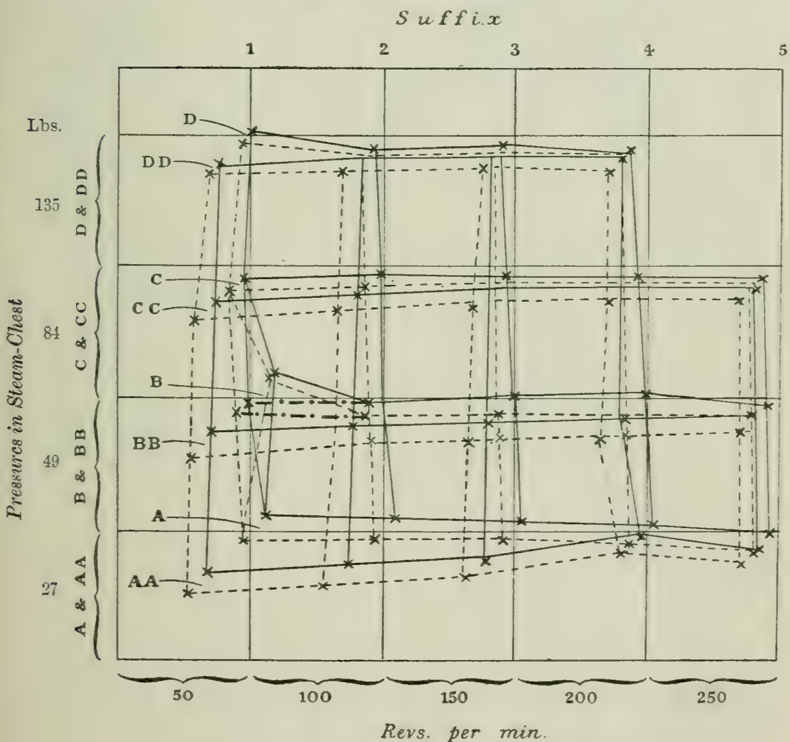
TABLE 8.

Trial.	Steam present in Cylinder as fraction of measured exhaust, neglecting leaks.		Dryness-fraction of Steam present in Cylinder if measured exhaust be corrected for leakage.			Theoretical dryness-fraction at release if expansion from cut-off were adiabatic.
	At cut-off.	At release.	At cut-off.	At release.	Dryness-fraction at release, if leakage into cylinder during expansion be deducted.	
	1	2	3	4	5	6
A_1	0·76	0·92	0·94	1·11	1·02	0·92
A_2	0·83	0·97	0·94	1·10	1·08	0·92
A_3	0·87	1·00	0·93	1·07	1·04	0·90
A_4	0·85	1·09	0·89	1·05	1·03	0·87
A_5	0·81	0·95	0·85	0·99	0·97	0·82
B_1	0·90	0·99	1·16	1·2	0·98	1·08
B_2	0·8	0·91	0·88	0·98	0·93	0·84
B_3	0·83	0·96	0·88	1·03	0·98	0·84
B_4	0·82	0·97	0·86	1·02	0·99	0·82
B_5	0·83	0·94	0·87	0·98	0·95	0·83
C_1	0·71	0·84	0·82	0·95	0·86	0·78
C_2	0·79	0·91	0·85	0·98	0·93	0·81
C_3	0·80	0·88	0·84	0·92	0·89	0·81
C_4	0·83	0·90	0·87	0·95	0·92	0·82
C_5	0·82	0·88	0·85	0·91	0·89	0·80
D_1	0·82	0·89	0·96	1·02	0·92	0·91
D_2	0·80	0·85	0·86	0·92	0·86	0·83
D_3	0·85	0·90	0·90	0·95	0·91	0·85
D_4	0·84	0·86	0·88	0·90	0·87	0·83
AA_1	0·46	0·60	0·53	0·68	0·64	0·52
AA_2	0·54	0·70	0·58	0·75	0·73	0·57
AA_3	0·60	0·75	0·64	0·80	0·74	0·62
AA_4	0·77	0·91	0·82	0·97	0·96	0·79
AA_5	0·71	0·84	0·74	0·87	0·87	0·73
BB_1	0·49	0·64	0·56	0·72	0·67	0·55
BB_2	0·61	0·74	0·65	0·79	0·76	0·64
BB_3	0·63	0·76	0·66	0·81	0·78	0·65
BB_4	0·67	0·81	0·70	0·84	0·80	0·68
BB_5	0·71	0·84	0·74	0·86	0·85	0·72
CC_1	0·52	0·65	0·59	0·73	0·66	0·58
CC_2	0·63	0·74	0·68	0·79	0·76	0·66
CC_3	0·68	0·80	0·71	0·84	0·81	0·70
CC_4	0·73	0·81	0·76	0·85	0·83	0·74
CC_5	0·72	0·81	0·74	0·83	0·81	0·72
DD_1	0·63	0·69	0·72	0·78	0·69	0·70
DD_2	0·68	0·78	0·73	0·84	0·79	0·71
DD_3	0·74	0·80	0·78	0·85	0·81	0·75
DD_4	0·74	0·82	0·76	0·85	0·81	0·74

in the cylinder at release as steam, if no leakage had taken place between cut-off and release, while Column 6 gives the dryness-fraction which would have resulted from an adiabatic expansion of the mixture present at cut-off. The difference

FIG. 37.

Diagram showing Variation of Dryness-Fraction at Cut-off and Release; with Speed and Pressure.



Dotted lines = Dryness fraction at cut-off
Full " = " " " Release

between the values in Columns 5 and 6, stated as a percentage of the steam and water actually in the cylinder at release, gives an approximately accurate determination of the quantity of

FIG. 38.

Curves showing Variation of Dryness-Fraction and Total Leakage up to Release (shaded area), with Pressure and Temperature.

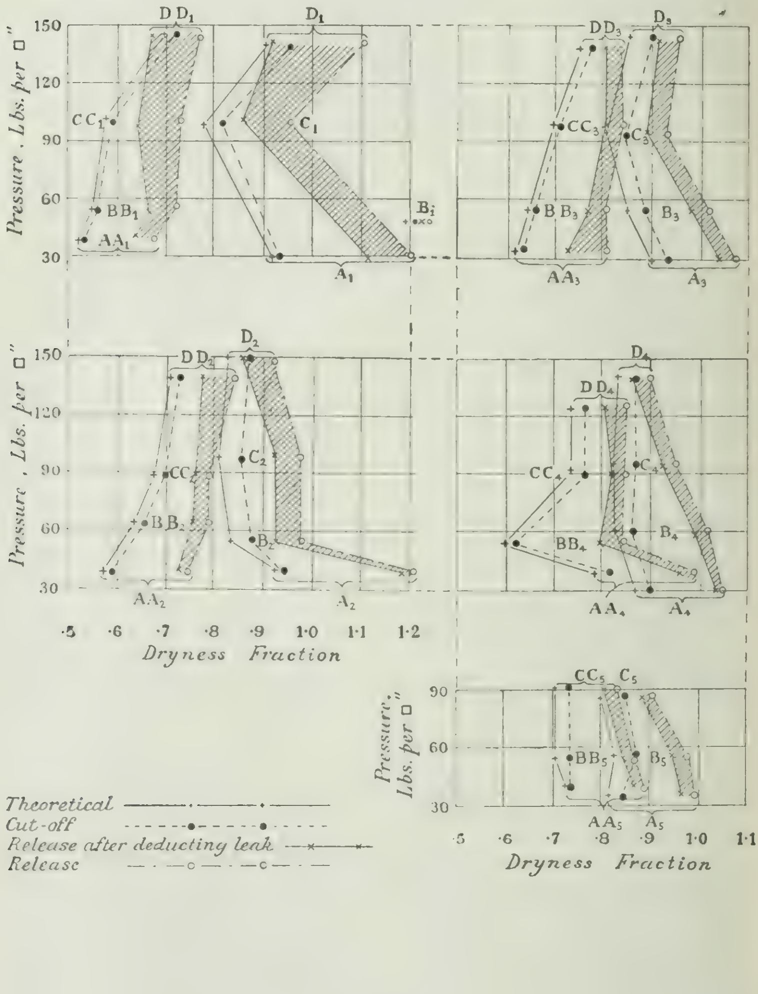
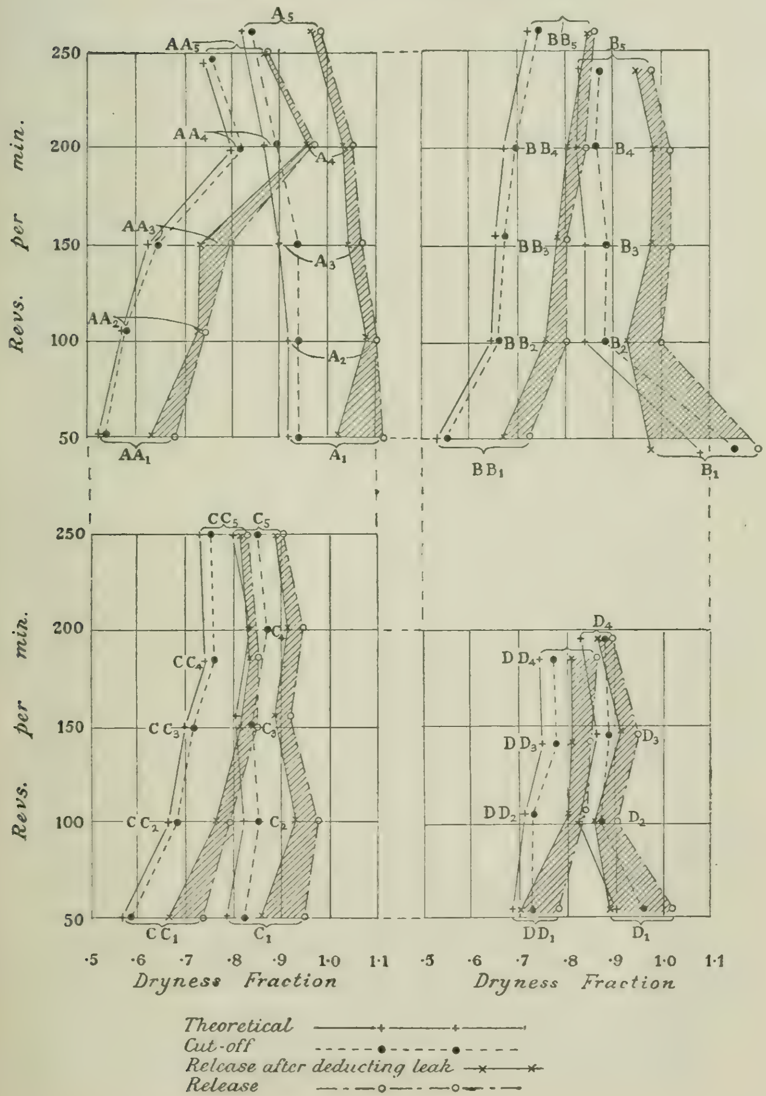


FIG. 39.—*Curves showing Variation of Dryness-Fraction and Total Leakage up to Release (shaded area), with Speed.*



steam which has been formed by re-evaporation during expansion. It must therefore be a measure of the regenerative action of the cylinder walls. It will be seen that in several instances the steam is not only dry but superheated at release. Such superheating only takes place on the jacketed trials, and there is strong internal evidence to show that in the most marked case, that of B_1, there was superheating throughout the stroke. In such a case, the leakage of the valves is very greatly reduced, and the values calculated from the leakage curves can no longer be relied on. From the curves of variation of the dryness-fraction given in Fig. 37 (page 229), it appears probable that the valve leakage on trial B_1, if it existed at all, was very small; in such a case the values of the dryness-fraction calculated without leakage, as given in Columns 1 and 2 of Table 8, represent much more closely the actual facts than the values in 3 and 4 of that Table. The superheating at admission in trials A_1, A_2, A_3, and A_4 has already been dealt with. Figs. 38 and 39 (pages 230 and 231) show the values of the corrected dryness-fraction at release, and the difference between the values in 4 and 5 has been shown hatched, the intercept between the two curves representing leakage up to release expressed as a percentage of the steam and water in the cylinder for each trial. The values have been plotted for both varying speeds and varying pressures. It will be noticed that as the leakage per hour when the engine is running is appreciably constant for all speeds, the leakage, expressed as a percentage of the mixture present in the cylinder, diminishes with speed for any pressure and increases with pressure for any speed. It will also be seen that the dryness-fractions for jacketed and unjacketed trials converge towards one another both with increase of temperature and increase of speed.

On Fig. 37 (page 229) is shown at a glance the dryness-fraction at cut-off and release for all the trials plotted horizontally on a scale of revolutions and vertically on a scale of pressures. It will again be seen that in both directions the dryness-fractions for jacketed and unjacketed trials converge towards one another and towards unity. The dryness-fractions at cut-off and release also clearly converge towards one another in both directions. There is only one marked

divergence from a straight line throughout the observations, namely, for both fractions for the B_1 (245° F. 50 revs. jacketed) trial. If the leakage correction for this trial be omitted, the fractions would, as shown, fall upon the proper straight lines. This was the trial when wire-drawing, and therefore initial superheating was a maximum, and thus the deduction already drawn, that in such a case leakage will be reduced or eliminated, is confirmed in a very interesting and instructive way.

Regenerative action of Cylinder Walls.—The area of walls and clearance surface of the cylinder up to cut-off is 1·355 square feet, and up to the end of the stroke is 2·6 square feet. To cover the surface up to cut-off with a film of moisture 0·001 inch thick would therefore require 0·0072 lb. of water. At the end of the stroke a similar film would weigh 0·0136 lb. Bearing these quantities in mind, an estimate of the thickness of the film of dew formed by condensation during admission on each trial could be made.

The following Tables 9 and 10 (page 234) give, first, the weight of steam condensed during admission, and, second, the net re-evaporation during expansion, after correcting for leakage.

Table 11 (page 235) gives approximately the corresponding average rate of interchange of heat in lb. F.° units per square foot of surface per minute, between the steam and the admission surfaces, and between the total cylinder surface and the steam during expansion.

Firstly—Condensation during Admission.—Table 9 shows that, excepting those trials at lowest speed where wire-drawing through the stop-valve has modified the results, the total condensation up to cut-off increases with increased pressure and temperature of admission. As the cut-off was constant, condensation therefore increases with the difference between the temperature of admission and exhaust. This difference of temperature is sensibly the same for the jacketed and unjacketed series, yet the condensation increases with increase of temperature in a much higher ratio on jacketed than on the unjacketed trials. For example, on the jacketed trials at 150 revolutions the condensation at 350° F. initial temperature is

TABLE 9.

Condensation on Cylinder Walls.

Suffix denoting Speed.	Revs.	Steam condensed during admission in lbs. per 1,000 strokes.							
		Jacketed Series.				Unjacketed Series.			
Admission temp.		A 245° F.	B 280° F.	C 315° F.	D 350° F.	AA 245° F.	BB 280° F	CC 315° F.	DD 350° F.
1	50	0·40	0	5·7	1·6	8·5	12·3	18·0	15·0
2	100	0·45	0·83	4·0	6·0	6·3	8·0	11·5	12·6
3	150	0·48	1·7	4·2	4·8	4·8	6·8	9·3	9·8
4	200	0·90	1·9	3·5	4·6	1·86	5 4	7·0	9·1
5	250	0·91	2·0	3·7	—	2·9	4·5	5 8	—

TABLE 10.

Re-Evaporation on Cylinder Walls.

Suffix denoting Speed.	Revs.	Steam re-evaporated during expansion in lbs. per 1,000 strokes.							
		Jacketed Series.				Unjacketed Series.			
Admission temp.		A 245° F.	B 280° F.	C 315° F.	D 350° F.	AA 245° F.	BB 280° F.	CC 315° F.	DD 350° F.
1	50	0·71	0	3·3	0·4	2·2	3·2	3·7	0
2	100	1·2	0·6	3·3	1·4	2·4	2·6	3·6	4·0
3	150	0·98	2·0	2·5	2·3	1·4	2·3	3·6	2·8
4	200	1·4	2·3	2·5	1·36	1·7	2·14	2·8	3·1
5	250	0·93	1·9	2·1	—	1·62	2·3	2·5	—

ten times the condensation at 248° F. initial temperature, while on the unjacketed trials at the same speed the condensation at 350° F. is only twice that at 245° F. On the other hand, the condensation on the

TABLE 11.

Mean Rate of Interchange of Heat between Cylinder Walls and Steam during the Forward Stroke.

Suffix denoting Speed.	Revs.	British Thermal Units per sq. ft. of exposed surface per minute transmitted from steam to walls during admission.							
		Jacketed Series.				Unjacketed Series.			
Admission temp.		A 245° F.	B 280° F.	C 315° F.	D 350° F.	AA 245° F.	BB 280° F.	CC 315° F.	DD 350° F.
1	50	65	—	1000	295	1460	2200	3100	2580
2	100	150	277	1370	1970	2250	2720	3920	4150
3	150	244	865	2190	2020	2460	3550	4850	4975
4	200	610	1320	2350	3000	1230	3580	4625	5700
5	250	795	1610	3100	—	2400	3990	5100	—
		British Thermal Units per sq. ft. of exposed surface per minute transmitted from walls to steam during expansion.							
1	50	36	—	183	25	119	180	200	—
2	100	123	62	350	145	269	276	373	448
3	150	155	318	410	348	224	423	575	423
4	200	297	490	525	270	350	460	548	605
5	250	255	480	555	—	420	635	655	—

unjacketed trial at 150 revolutions and 245° F. initial temperature is ten times that for the jacketed trial at the same temperature and speed, while at 200 revolutions and 350° F. temperature the condensation

without jackets is only twice that with jackets at the same temperature and speed. These facts bear out the conclusion arrived at below from a consideration of the variation of initial condensation expressed as a percentage of the steam entering the cylinder, that *the losses due to condensation on the cylinder walls of unjacketed engines diminish with increased initial pressure and temperature for a given ratio of expansion, quite independently of the influence of speed.* There are not wanting indications in the results here recorded, that if only the initial temperature could be sufficiently raised, jacketed and unjacketed engines would be equally efficient as regards initial condensation.

TABLE 12.

Suffix denoting Speed.	Revs.	Steam entering Cylinder up to Cut-off in lbs. per 1,000 strokes corrected for Leakage.							
		Jacketed Series.				Unjacketed Series.			
Admission temp.		A 245° F.	B 280° F.	C 315° F.	D 350° F.	AA 245° F.	BB 280° F.	CC 315° F.	DD 350° F.
1	50	7·7	12·2	30·9	38·6	18·6	29·9	44·8	53·7
2	100	7·8	15·2	27·8	43·0	15·2	23·3	36·0	46·9
3	150	7·1	15·0	27·2	40·7	13·4	20·4	32·8	44·9
4	200	8·4	13·7	26·8	37·6	10·7	19·2	29·7	38·1
5	250	9·4	15·5	24·1	—	11·5	17·3	26·8	—

Secondly.—Total condensation during admission.—This decreases with increase of speed throughout the unjacketed series of trials, with the single exception of the trial at 200 revolutions and 245° F. initial temperature. This trial has already been noted as one which was largely affected by superheating due to wire-drawing through the stop-valve. On the jacketed series, on the two higher temperature series, the same decrease of total condensation with increase of speed is observable, but on the two lower temperature-series the opposite is the case—the total condensation increasing with speed. This

apparent anomaly is probably largely due to the fact that throughout these two last-named series the weight of steam entering the cylinder is comparatively small, and increases rapidly with speed, so that as shown later the condensation expressed as a percentage of the steam entering the cylinder does not increase with the total condensation. The total condensation on these series is moreover so small that the heat transference is at a comparatively low rate, so that increase of speed does not affect the result to the same extent as where larger weights of steam are in question. It is noticeable that the actual rate of heat transference as shown in Table 11 (page 235) increases regularly with speed and with temperature. The weight of steam entering the cylinder as shown in Table 12 increases with speed (with one or two exceptions) during the 245° and 280° F. jacketed series, but decreases with speed in all other cases except those already noted as anomalous.

Thirdly.—Rate of Interchange of Heat between Steam and Cylinder Walls.—Table 11 gives the rate of interchange of heat from steam to cylinder walls during admission, and from walls to steam during expansion. It will be noticed that the rate of interchange of heat from the steam to the walls on the unjacketed trials approximates to twice that on the jacketed trials. This corresponds to the greater depth to which the cyclical temperature variation penetrates, when the mean temperature of the cylinder walls is lowered by the absence of jackets. This has previously been pointed out by Messrs. Donkin, Callendar and Nicolson, and other observers, but is here quantitatively analysed for the first time, as far as the reporter is aware.

Fourthly.—Re-evaporation during Expansion.—During expansion the total weight of steam evaporated, including that liquefied by expansion, has a maximum value of about 3·5 lbs. per 1,000 strokes. It is important to realise that this maximum appears to be sensibly the same on both jacketed and unjacketed trials. Generally the evaporation without jackets is greater than with jackets, showing that the regenerative action of the cylinder walls during expansion

is not appreciably helped by jacketing. During expansion there is not time for the higher mean temperature of the walls when jacketed to influence the evaporation by conduction. When the cylinder is unjacketed there is a much larger weight of condensed moisture to draw from than when jacketed, and it will be noticed that the evaporation on the jacketed trials in many cases approximates to the total condensation, so that no large increase could be looked for, while on the unjacketed trials this is only the case on the higher speed trials. Yet in neither series does the evaporation appear to vary at all closely with the condensation, though there are some indications of such a tendency.

Further, the mean rate of heat transmission from the walls to the moisture is in all cases extremely low compared with the rate of transmission in the reverse direction during admission, so that it seems difficult to believe that the limit of evaporation is in any case reached, even though it be assumed that the evaporation takes place chiefly towards the end of expansion, so that the actual rate is much higher than the mean.

It appears clear, therefore, that the jackets have little, if any, influence upon evaporation during expansion, and that under the conditions under which these trials were carried out the regenerative action of the walls is quite as high without jackets as with them, even at the low speeds where the jacketed engine is largely more economical than the unjacketed.

Influence of Ratio of Steam in Jackets to Steam through Cylinders upon Condensation and Re-evaporation.—From Cols. 19, 20 and 22 of Table 13 (page 253), fifthly, it will be seen that the ratio of thermal units through the jackets to the thermal units passed through the cylinder varies between very wide limits. For example, on the trial at 245° F. temperature and 50 revolutions the value of this ratio was 0·724, while on the trial at 356° F. temperature and 200 revolutions it was 0·042. The reporter has sought in vain for any indication, either in the condensation, re-evaporation, or the heat consumption that this variation has any influence which can be reduced to law. The former of these trials has condensation on the walls equal to

0·40 lb. per 1,000 strokes as compared with 0·45 lb. on the 245° F.-100 revolutions trial. The re-evaporation in the first is less than the last, being 0·71 as against 1·2 for the 245° F.-100 revolutions trial, while the efficiency ratio, excluding the jacket steam, is 0·486, as compared with 0·625 for the 245° F.-100 revolutions trial. Any indication of influence therefore is in the contrary direction to what would be expected. The variation is in the direction in which variation would have been expected from the relative conditions of the two trials, without regarding jackets at all. The same in a less degree is true of all the variations in jacket steam throughout the trials. Any excessive number of thermal units absorbed in the jackets, however, as for example is the case with the A_1 and A_3 trials (at 245° F., 50 and 150 revolutions), coincide, with an abnormal total consumption of heat per I.H.P. per minute.

Ratio of Steam present in the Cylinder at Cut-off to Total Steam and Moisture; Dryness-Fraction at Cut-off.—The relationship between initial condensation and the steam passing through the cylinder can best be studied by examining the variations of the complement—the dryness-fraction. This can best be seen by comparing the temperature entropy diagrams for the whole series.

Temperature Entropy Diagrams.—Entropy temperature diagrams have been drawn for all the trials, and have been superimposed in two series—the one set showing variation with increase of speed, the other with increase of initial pressure. On these latter, necessary corrections for leakage have been made. So as to make them comparable with diagrams drawn without allowance for leakage, they have been plotted for 1 lb. of total exhaust condensation water. The leakage has then been deducted at cut-off and release, so that, after deducting the enclosed area, the entropy of the steam measured on the indicator diagram compared with the entropy up to the edge of the enclosed leakage area represents the real or corrected dryness-fraction. To express with scientific accuracy the actual entropy temperature changes, it would be more correct to plot the diagram upon a new scale, in which the entropy of the steam, after

deducting leakage, was the unit. Such a diagram would not however show so clearly the effect of allowance or non-allowance for leakage in altering the relationship between steam and moisture in the cylinder.

Comparing first the superimposed diagrams for constant temperature and varying speeds and for convenience dealing with the unjacketed series first,—at the lowest pressure, namely the AA series, it will be noted that the expansion lines of the entropy diagrams are roughly parallel to one another, and that the proportion of steam present both at cut-off and at release increases in a regular sequence with the speed, with the exception of the AA_4 trial, which is exceptional. In the BB series the same uniform and regular increase in the dryness-fraction occurs without exception throughout the whole series. The 100-revolution trial however, shows deviation from parallelism to the other trials on the expansion curve. The condensation is less and the re-evaporation more than the relative speed would indicate. In both the above series the improvement in the dryness-fraction due to increase of speed diminishes as speed increases, the curves for the higher speeds closing up upon one another. In the CC series this is still more marked, the expansion curves for the three higher speeds being almost identical, so that at 150 revolutions per minute and at an admission temperature of 315° F., the effect of speed upon the dryness-fraction both at cut-off and release is practically reduced to zero. On the DD series this point is still further emphasised, at 100 and 150 revolutions (the admission temperature being 350° F.) the speed seems to have no further effect in increasing the dryness-fractions at cut-off and release.

Turning to the jacketed series, on the A series of trials at lowest pressure (the mean admission temperature for all the trials being about 245° F.), the effect of the jackets is at once apparent; all the expansion lines being brought closer to the theoretical saturation curve. All the trials seem to show closely the same results as regards percentage initial condensation; the jackets have therefore produced, in the lowest pressure series, the same result of closing up trials at different speeds upon one another that was shown on the unjacketed

series in the highest pressure series, and at the same time all the trials have been brought closer to the ideal of maximum dryness fraction.

On the B series of trials the jackets have so far affected the result that percentage initial condensation seems to depend no longer upon speed but upon the minor accidental conditions under which the trials are run. The variations in dryness-fraction are smaller than those of the unjacketed series previously referred to. With regard to the C trials the same remarks may be made, and so also with regard to the D series at the highest pressure. All the trials show very nearly the same percentage of initial condensation. The jackets therefore have so far influenced the result as practically to eliminate, except at the lowest speeds and pressures, the effect of speed upon percentage initial condensation.

If the diagrams for the corresponding jacketed and unjacketed trials be compared, one or two points of importance are apparent. Generally the expansion curve on the temperature entropy diagram for the unjacketed trial is very closely parallel to that of its jacketed counterpart, showing graphically what has already been noted that re-evaporation during expansion is as great on the unjacketed as on the jacketed trial. In some cases it is greater on the unjacketed trial. It will be noticed also that as the speed increases for any pressure the diagram for the unjacketed trial closes up upon its jacketed counterpart, until at the higher pressure of any speed the two come comparatively close to one another. In no instance, however, does the unjacketed diagram reach the jacketed diagram at the speed or pressure included within the range of the trials until the jacket steam has been added to the steam passing through the cylinder.

Further, a comparison of the diagrams accentuates the fact already referred to that both total condensation and dryness-fraction generally increase with increase of admission pressure and temperature for a given speed on the unjacketed trials. This does not at first sight appear logical.

Referring to Tables 6 and 7 (pages 224 and 227) however, a probable explanation becomes apparent. Due to the constant ratio of

expansion the range of temperature between cut-off and release does not increase in anything like the same ratio as the increase of initial temperature. Taking the 50-revolutions series, the range of temperatures during expansion on the lowest pressure trial, namely, AA_1 is 39° F., on the second pressure trial BB_1 33° F., on the third CC_1 46° F., and on the fourth DD_1 56° F.

This increase in range is accompanied by a very much larger increase in the difference between release and exhaust temperatures. Following the trials in the same order—on the AA_1 trial the drop from release to exhaust is 12° F., on the BB_1 41° F., on the CC_1 68° F., and on the DD_1 86° F. The temperature at which the cylinder walls and end surfaces is dry will be lower than the temperature of release, but will rise as the temperature of release rises, and it may be assumed upon previous evidence, that the surfaces after once becoming dry are not reduced in temperature to any very great extent. If this be true, the range of variation in the temperature of these surfaces will not increase in anything like the same ratio as that in which admission temperature is increased. At the lower pressure trials therefore, especially at the lower speeds, the cylinder walls and end surfaces will not become dry nearly so quickly nor so early in the return stroke as on the higher admission pressure trials, even if they become entirely dry at all.

A further explanation is to be found in the fact, to which reference has already been made, that the higher the admission pressure, the larger is the weight of steam admitted per square foot of surface. On referring again to Table 12 (page 236), where the weight of steam present per 1000 strokes on the respective trials is given, it will be noted that on any speed series the weight of steam per 1000 strokes increases in a nearly constant ratio; so that if the maximum limit of condensation is reached in any given case, the dryness-fraction for any higher pressure must of necessity increase in proportion to the increase of weight of steam admitted per square foot of surface. The ratio of increase of the dryness-fraction for a given rise of pressure will also be affected by the speed; and on comparing the different speed series, very interesting information is obtained bearing upon the pregnant suggestions thrown out by Messrs.

Callendar and Nicolson. On the jacketed series, as the whole phenomena of condensation are modified by the raised mean temperature of the cylinder metal and walls, the relative effect of improved dryness-fraction due to increased temperature at admission will be diminished, and it is therefore found that on the diagrams for the jacketed series the dryness-fraction tends to vary much less and less regularly than in the unjacketed series, and the variation at the higher speeds is in many cases in the reverse direction.

Range of temperature has therefore a larger effect upon the initial condensation, as the other conditions have been brought closer into equilibrium by the introduction of an artificially raised surface temperature, and causes reduction in the dryness-fraction instead of the increase shown where the other governing conditions are more variable and more powerful.

As the speed increases, and the ranges of temperature during expansion at the various pressures close up to one another, the difference between release temperature and exhaust becomes less than at the lower speeds. Added to this, the time during which condensation and cooling can take place is reduced, and the resulting benefit is shown most markedly in those cases which at the slow speeds were worst, namely, on the low-pressure trials.

At the highest speeds, therefore, the difference due to the higher critical dry temperature will be diminished, and the indirect benefit upon initial condensation tends to be neutralised and swamped by the larger benefit from increased speed which is shared in common.

To show the re-evaporation during expansion, the adiabatic for the mixture of steam and moisture present at cut-off has been drawn upon each temperature-entropy diagram, and the projection of the toe of the diagram beyond this adiabatic line will represent the re-evaporation due to regenerative action of the cylinder walls. At the higher speeds of the jacketed trials an interesting point is incidentally shown. There is a general tendency for the dryness-fraction at cut-off for the individual trials of any speed series to follow an adiabatic curve, so that the dryness-fraction for intermediate trials of the series can be very closely predicted from that found at

either extremity of the range of pressure by drawing an adiabatic curve for the given proportions of steam and water through that extremity.

On Figs. 21 to 30 (pages 198–207) the leakage deduction has been plotted on the temperature entropy diagram, showing the effect of this necessary allowance on the dryness-fractions at cut-off and release.

Diagrams of Steam Consumption. Willans lines, etc.—In Fig. 40 (page 245) will be found curves in which the ordinates represent pounds of steam used in the cylinder per hour, the abscissæ representing revolutions per minute. The full lines represent for each pressure series the total measured steam-consumption per hour when jacketed. The dot and dash lines represent the corresponding consumption, including jacket steam, and the dash lines represent in corresponding units the consumption when unjacketed. These diagrams simply confirm the results obtained by Mr. Willans in his classical experiments, and graphically show how the weight of condensed steam increases as the mean pressure—that is to say, as the work done in the cylinder—increases. In the present case including the jacket steam, these diagrams show that at the higher pressures and temperatures the consumption of the jacketed engine is as large as the unjacketed even at the lower speeds. An approximate thermal unit scale has also been added showing the comparison on a direct heat basis. Figs. 41 and 42 give the corresponding values of steam and heat units consumed on an effective pressure base.

Fig. 43 (page 247) shows the total weight of steam per hour and the B.Th.U.'s per minute consumed by the engine on a H.P. base.

General Conclusions.—It is dangerous to draw conclusions of too general and sweeping a character from experiments upon one type of engine under one set of conditions, but it may fairly be claimed that the ground covered by this Report has never previously been surveyed with an engine showing more consistent and definite results, nor under conditions which enabled so detailed an analysis of the results

FIG. 40.

Steam Consumption in Lbs. per Hour.

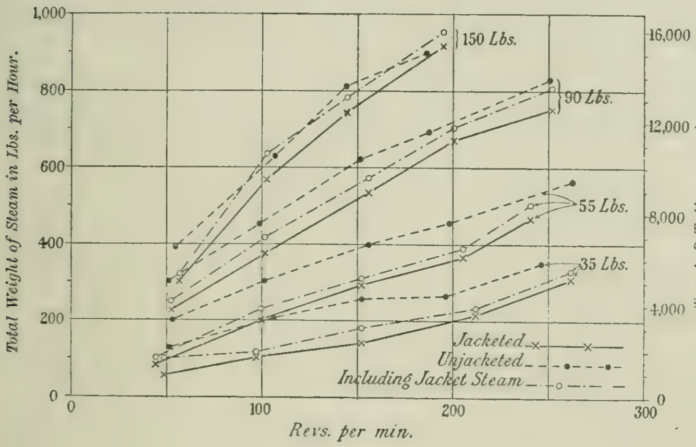
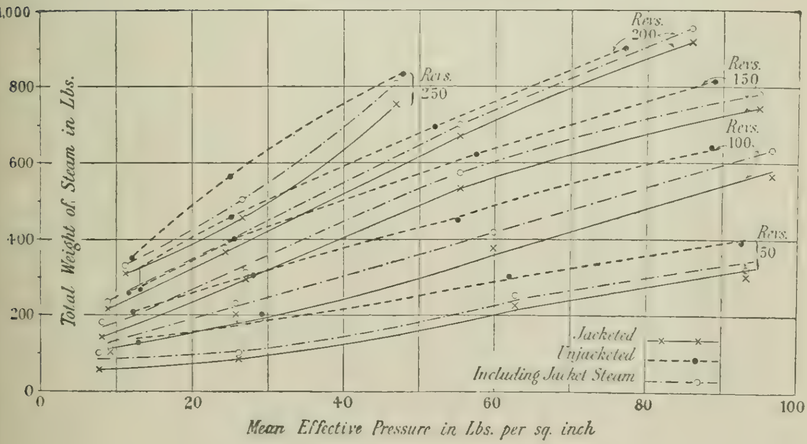


FIG. 41.

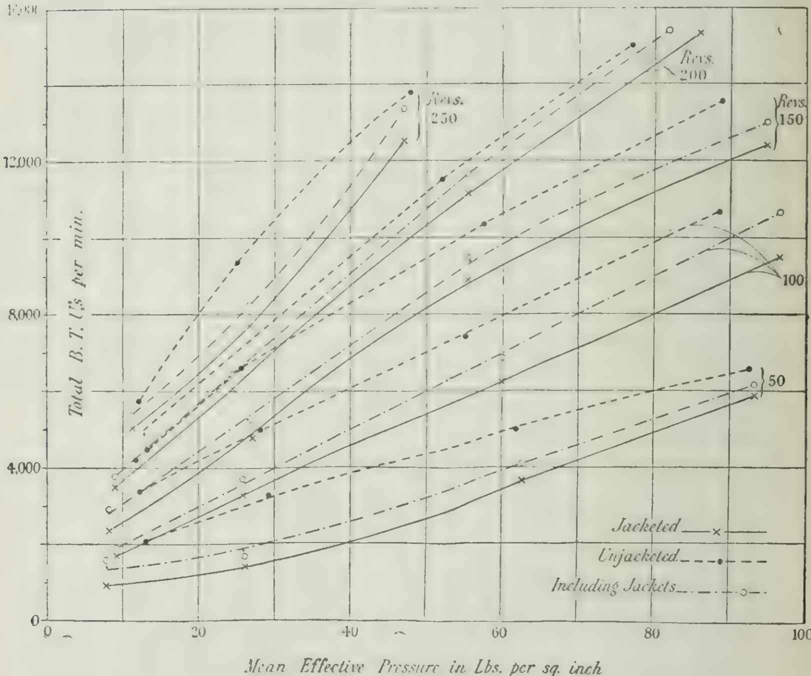
Total Weight of Steam in Lbs.



to be made. It may therefore be anticipated with some confidence that the definite indications shown by the results form a real contribution to the present knowledge of the phenomena accompanying condensation and re-evaporation in an engine cylinder under given conditions of jacketing. The points which have been elucidated may be summarised as follows:—

Firstly, leakage through the slide-valve, to the importance of which Messrs. Callendar and Nicolson have drawn attention, has

FIG. 42.—*Total B.Th.Units per minute.*



been quantitatively determined under defined conditions, and has been shown to be nearly independent of speed of sliding surface and proportional to difference of pressure between the two sides of the valve. Further, it has been shown that the assumption that the leakage is inversely as the overlap of the valve is at least in the main well

FIG. 43.—*Lbs. of Steam (measured) per Hour.*

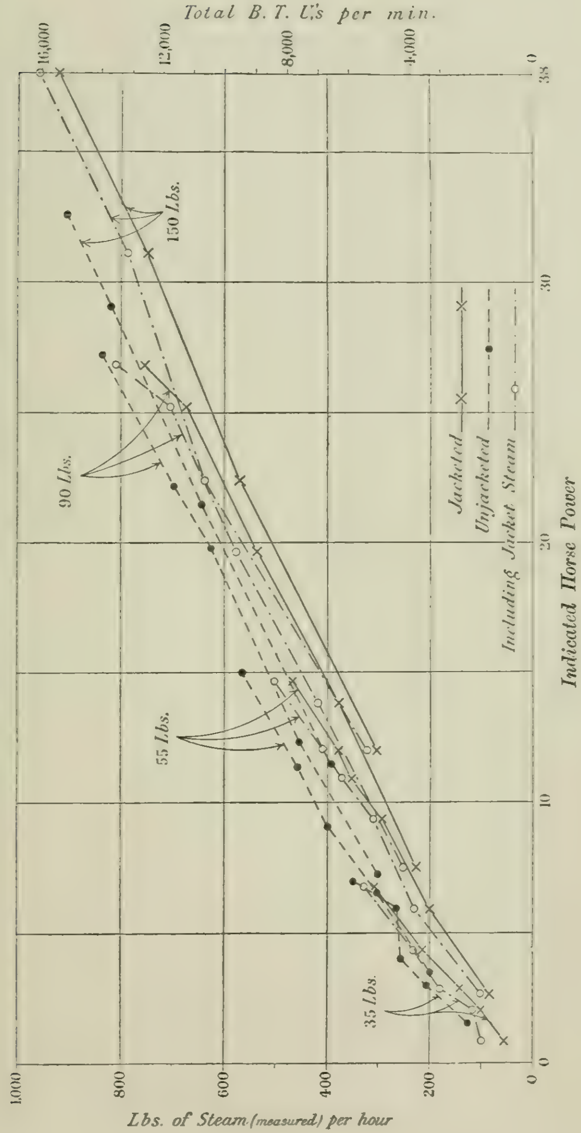


Fig. 44.

B.Th.Units per I.H.P. per min.

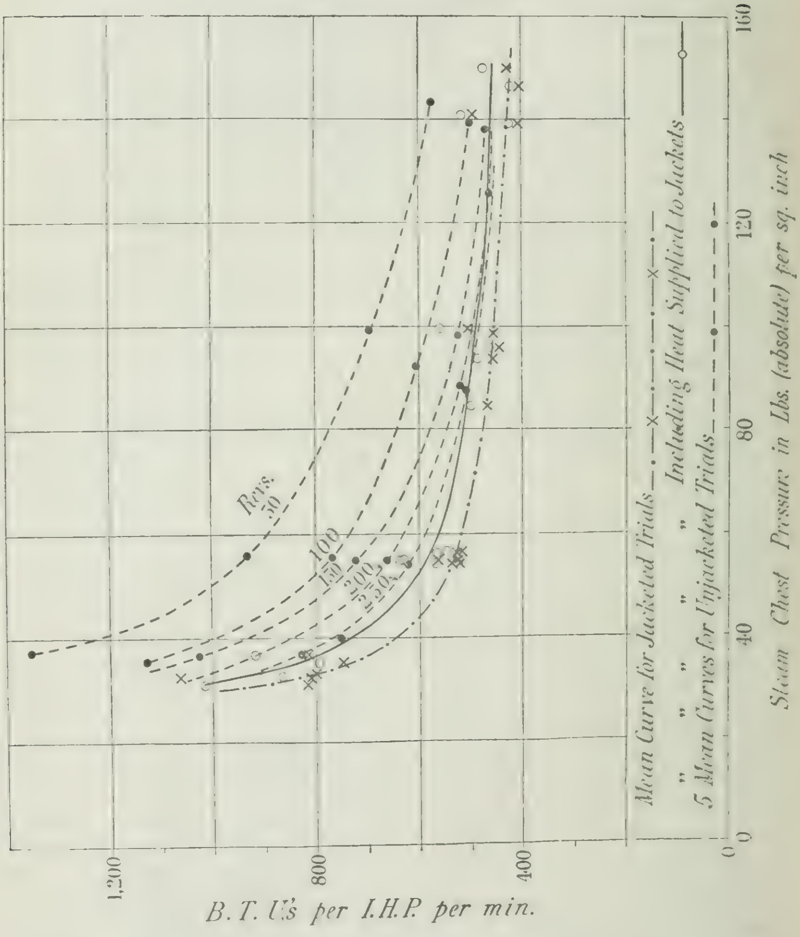
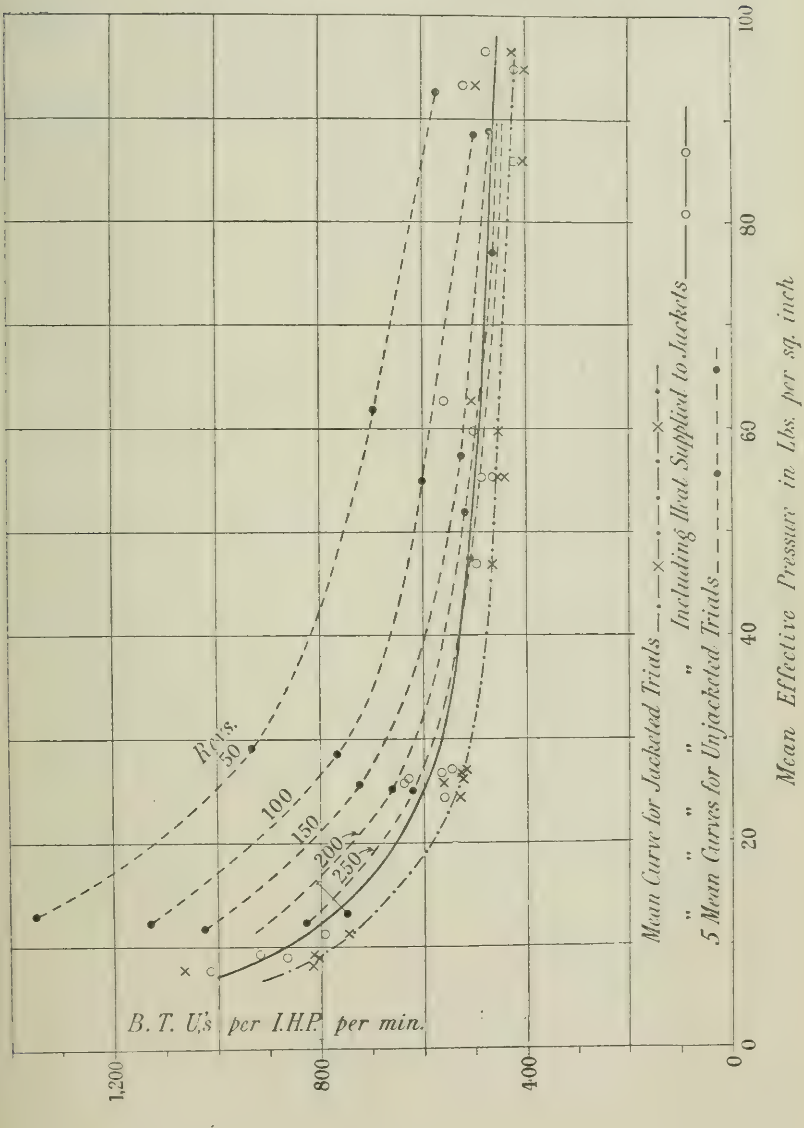


FIG. 45.

B.Th.Units per I.H.P. per min.



founded. And further, that with well fitted valves the leakage may amount to over 20 per cent. of the steam entering the cylinder, and is rarely less than 4 per cent.

Secondly, it has been shown that for an unjacketed engine with a given ratio of expansion initial condensation, expressed as a percentage of the steam in the cylinder, *diminishes* with increase of initial temperature, while the total condensation per stroke *increases* with such temperature increase.

This, though suggested by Messrs. Callendar and Nicolson's researches, has never previously been demonstrated with clearness, as if leakage is not allowed for, the results are obscured and even reversed, and the conclusions arrived at without leakage allowance are therefore unreliable.

Thirdly, it appears from the results here obtained that the re-evaporation for a given ratio of expansion is as great and sometimes greater without jackets than with them. This shows very clearly that the regenerative action of the cylinder walls with a given ratio of expansion is largely independent of their mean temperature.

No quantitative analysis of re-evaporation is possible where leakage is not taken into account, as without the necessary allowance results would be largely illusory.

Fourthly, it is possible from the results obtained to show the temperature when, for any speed of revolution with a given rate of expansion, the jackets will become unnecessary or wasteful. If the heat units per I.H.P. per minute required by the unjacketed engine for each speed of the series be plotted either on an initial pressure or a mean effective pressure base the points for each speed will be found to lie on four curves, which become closer and closer to one another as the speed increases, and all converge to a point as pressure or temperature increases. If the heat consumption for the jacketed series be likewise plotted, it will be found that the points for the different speeds at each pressure lie irregularly round a point, their exact position being determined by the accidentally slight variations of the conditions of each trial. A fair curve through the means of these points will lie below the corresponding curves for the unjacketed trials, but if the heat absorbed in the jackets be

included, the resultant curve cuts the unjacketed curves at points which for each speed indicate the temperature and pressure at which the jackets cease to be economical. Such curves are shown on Figs. 44 and 45 (pages 248 and 249). It will be seen that the full black line, which is the resultant mean for the jacketed trials, cuts both the 250 and the 200-revolution unjacketed curves within the temperatures and pressures included within the scope of the present experiments, and the temperatures and pressures where the 150, 100, and even the 50-revolution curves would cut, can very closely be predicted. As far as the reporter is aware, this is the first time when an exact determination for a given engine and ratio of expansion of this point has been diagrammatically shown.

In conclusion, the reporter wishes to thank most cordially the assistants who have so generously and ungrudgingly spared neither time nor thought in helping him in the arduous work of these trials extending over six years, and in working out and co-ordinating the results. Without their aid the work and the Report would have been impossible. To Professor H. M. Waynforth, especially, thanks are due for many excellent and fruitful suggestions, for ungrudging assistance in carrying out the trials and looking over, correcting and criticising the proofs, and to Mr. W. Mason for the care, thought, and originality he showed in carrying out the reporter's suggestions with regard to the leakage trials and in devising the empirical leakage area diagrams. The work done by the late Mr. James, whose untimely death has delayed the production of this Report, and has been a very serious loss, was admirably reliable. To Mr. Kiernan, as well as many of the reporter's students, thanks are also due.

The Report is illustrated by 45 Figs. and 14 Tables in the letterpress, and is accompanied by two Appendices (page 256).

TABLE 13. SERIES I.—*Jacketed Trials* (*continued on next page*).

Trial.	Duration. Minutes.	Pressures. Lbs. per sq. inch.			Revs. per min.	Nett Brake Weight in lbs.	B.H.P.	I.H.P.	Steam through Cylinder in lbs.					Steam through Cylinder Jackets.
									From Cards.		Measurement by Weight.			
		Steam before inlet abs. 1	Steam chest abs. 2	Mean effective. 3	4	5	6	7	Per min. 8	Per hour. 9	Total. 10	Per hour. 11	Per hour deducting Leakage. 12	Per hour. 13
A_1	30	39·2	32·5	7·8	48·5	—	—	0·87	0·74	41	28	56	46	44
A_2	20	39·2	37	9·2	97·2	—	—	2·06	1·58	91	34	102	90	14·25
A_3	44	44·7	31	8·2	152·1	—	—	2·86	2·29	137	104	141·8	132	37·8
A_4	20	47·1	33·2	9·6	203	—	—	4·45	3·20	192	72	216	205	18·75
A_5	30	44·2	35·5	11·3	261·4	—	—	6·77	4·61	276	154	308	297	21
B_1	25	75·8	55·1	26·1	44·5	79·6	1·72	2·66	1·31	78	35	84	66	18
B_2	30	67·6	55	25·8	99·4	76·9	3·71	5·87	2·75	165	100	200	182	29
B_3	30	74·0	56·7	27·1	151·7	81·8	6·02	9·39	4·36	261	146	292	274	18
B_4	30	72·2	54·4	23·5	203·5	58·3	5·76	10·93	5·39	323	177	354	337	17·75
B_5	30	66	56·4	26·7	240	44·5	8·21	14·67	6·72	403	233	466	448	36·5
C_1	35	99·7	99·7	62·6	52·4	234·6	6·21	7·49	2·90	173	132	226·3	196	26·31
C_2	30	102·0	98·7	59·7	104·5	217·6	10·71	13·84	5·15	309	188	376	346	42·0
C_3	30	107·6	93·9	55·3	155·3	200·8	15·12	19·63	7·46	447	267	534	505	39·5
C_4	30	101·7	96	55·3	200	188·0	18·24	25·25	9·42	565	335	670·5	641	33·5
C_5	30	92·7	84·5	46·8	251	160·5	19·54	26·82	10·37	622	376	752	725	56
D_1	20	164·7	141	93·2	56·5	373·5	10·24	12·04	4·3	258	101	303	262	18·375
D_2	30	157·3	149·7	96·5	101·9	364·9	18·03	22·44	7·78	466	284	568	525	68·5
D_3	20	151·5	146·5	94·8	143·9	344·0	24·01	31·14	10·83	649	248	744	702	37·5
D_4	20	157·5	139·3	85·9	194·2	311·2	29·32	38·1	13·11	786	306	918	818	39·75

TABLE 13 (*continued from opposite page*).

Trial.	Duration. Minutes.	Steam per I.H.P. in Cylinder in lbs. per hour.			Upper limit of Temp. Abs. F. T1.	Lower limit of Temp. Abs. F. T2.	B.Th.U. for actual engine per min. per I.H.P.	B.Th.U. per min. per I.H.P. in jackets.	Total B.Th.U. cols. 19+20.	Value of ratio $\frac{\text{jackets}}{\text{cylinder.}}$ Cols. 20/19.	B.Th.U. required by Standard Engine of Comparison per min. per I.H.P.		Efficiency Ratio of Actual to Standard.		
		Cards.	Measured.	Ditto if Leakage is deducted.							Rankine.	Carnot.	Cols. 23/19 to Rankine.	Including jackets. Col. 23/21.	Cols. 24/19 to Carnot.
		14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
A_1	30	51·5	64·6	52·8	727	670	1062	769	1831	0·724	570	510	0·486	0·311	0·480
A_2	20	44·5	49·5	43·6	727	670	814	104	918	0·127	570	510	0·635	0·620	0·626
A_3	44	48·0	49·6	46·1	734	670	815	200	1015	0·245	505	493	0·613	0·497	0·603
A_4	20	43·1	48·5	46·0	738	671	798	61	859	0·076	483	471	0·605	0·562	0·599
A_5	30	40·9	45·5	43·8	734	670	747	47	794	0·062	510	493	0·673	0·642	0·659
B_1	25	29·4	31·6	24·8	769	670	525	104	629	0·198	345	331	0·657	0·548	0·630
B_2	30	28·1	34·0	31·0	761	673	563	75	638	0·133	390	365	0·692	0·611	0·648
B_3	30	27·8	31·1	29·0	767	669	517	29	546	0·056	349	330	0·676	0·639	0·638
B_4	30	29·5	32·8	30·8	765	670	537	31	568	0·057	358	341	0·667	0·630	0·634
B_5	30	27·4	31·8	30·4	759	670	527	38	565	0·072	374	356	0·709	0·662	0·674
C_1	35	23·1	30·2	26·1	788	671	504	54	558	0·107	301	285	0·597	0·539	0·565
C_2	30	22·1	27·1	25·0	790	671	453	47	500	0·104	298	283	0·658	0·596	0·623
C_3	30	22·8	27·2	25·8	794	673	455	31	486	0·068	293	280	0·645	0·603	0·615
C_4	30	22·3	26·5	25·5	789	672	442	20	462	0·045	303	284	0·685	0·656	0·641
C_5	30	23·2	28·0	27·0	783	673	466	32	498	0·068	317	302	0·681	0·636	0·649
D_1	20	21·4	25·1	21·7	827	670	494	24	518	0·048	240	223	0·522	0·463	0·450
D_2	30	20·8	25·3	23·4	823	670	426	47	473	0·110	246	229	0·577	0·520	0·537
D_3	20	20·8	23·8	22·5	820	673	401	19	420	0·047	252	237	0 628	0·600	0·590
D_4	20	20·6	24·1	23·0	822	673	405	17	422	0·042	250	233	0·618	0·592	0·575

TABLE 14. SERIES II.—*Unjacketed Trials* (*continued on next page*).

Trial.	Duration. Minutes.	Pressures. Lbs. per sq. inch.			Revs. per. min.	Nett Brake Weight in lbs.	B.H.P.	I.H.P.	Steam through Cylinder.				
									From Cards.		Measurement by Weight.		
		Steam before inlet abs.	Steam chest abs.	Mean effective.					Per min.	Per hour.	Total.	Per hour.	Per hour deducting leakage.
		1	2	3	4	5	6	7	8	9	10	11	12
AA_1	40	51·5	37·6	13·0	51·4	27·3	0·68	1·53	0·98	59	84	126	114
AA_2	25	49·5	35·7	12·3	106·5	25·5	1·32	3·00	1·93	115	86	206	194
AA_3	30	48·4	36·7	11·8	152	22·9	1·69	4·1	2·70	161	128	256	244
AA_4	20	59·7	40	13·2	196·0	20·5	1·95	5·93	3·51	210	88	264	251
AA_5	20	48·9	37	12·4	245·7	—	—	6·96	4·23	253	117	351	339
BB_1	30	57·8	56	29·2	53·0	94·1	2·42	3·45	1·66	99	100	200	182
BB_2	25	57·5	55·7	28·1	101·3	80·3	3·94	6·50	3·01	180	126	302	284
BB_3	30	57·8	55	25·6	155·6	71·3	5·38	9·12	4·28	256	200	400	382
BB_4	35	57·7	55	25·2	197·8	60·2	5·77	11·39	5·27	316	266	456	438
BB_5	15	61·7	54·2	25·0	262·3	52·5	6 68	15·01	6·99	419	141	564	546
CC_1	30	105·2	99·4	61·9	51·2	236·3	5·87	7·24	3·05	183	151	302	272
CC_2	15	93·1	90·2	55·0	98 3	208·3	10·17	12·35	4·93	295	113	452	424
CC_3	30	105·2	98·2	57·4	151	208·3	15·25	19·8	7·80	468	311	622	592
CC_4	20	99·9	88·6	52·0	186·7	171·4	15·98	22 2	8·72	522	231	693	665
CC_5	20	105·1	87·5	47·7	249·9	154·4	18·71	27·24	10·75	645	279	831	804
DD_1	15	160·4	143·5	92·5	54·5	388·4	10·27	11·51	4·03	241	98	392	350
DD_2	15	150·9	139·4	88·5	106·3	355·4	18·33	21·49	7·49	449	160	640	599
DD_3	25	144·1	137·9	88·8	143·4	336·0	23·37	29·08	9·93	596	339	813	773
DD_4	10	135·3	125·8	77·0	185·5	280·0	25·19	32·62	11·74	704	150	900	863

TABLE 14 (*concluded from opposite page*).

Trial.	Duration. Minutes.	Steam per I.H.P. in Cylinder in lbs. per hour.			Upper limit of Temp. Abs. F. T 1.	Lower limit of Temp. Abs. F. T 2.	B.Th.U. for actual engine per min. per I.H.P.	B.Th.U. required by Standard Engine of Comparison per min. per I.H.P.		Efficiency Ratio of Actual to Standard.	
		Cards.	Measured.	Ditto if Leakage is deducted.				Rankine.	Carnot.	Cols. 19/18 to Rankine.	Cols. 20/18 to Carnot.
		13	14	15	16	17	18	19	20	21	22
AA_1	40	38·5	82·2	74·5	744	673	1351	455	441	0·349	0·326
AA_2	25	38·4	68·6	65·0	741	673	1128	470	460	0·418	0·408
AA_3	30	39·5	62·4	59·5	740	673	1026	473	465	0·460	0·453
AA_4	20	35·4	44·4	42·3	753	672	750	414	392	0·563	0 523
AA_5	20	36·4	50·4	48·7	741	673	828	483	465	0·570	0·561
BB_1	30	28·2	56·4	52·7	751	671	932	414	397	0·444	0·425
BB_2	25	27·8	46·5	43 7	751	673	768	414	397	0·539	0·517
BB_3	30	28·1	43 8	41·7	751	672	724	414	397	0·539	0·548
BB_4	35	27·7	40·0	38·3	751	672	661	414	397	0·572	0·600
BB_5	15	27·9	37·5	36·3	755	671	622	400	378	0·552	0·607
CC_1	30	25·3	41·7	37·5	792	673	695	299	283	0·430	0·406
CC_2	15	23·9	36·2	34·3	783	673	603	317	302	0·525	0·500
CC_3	30	23·6	31·4	30 0	792	673	523	299	283	0·570	0·540
CC_4	20	23·5	31·2	30·0	782	672	519	319	203	0·615	0·390
CC_5	20	23·6	30·5	29·5	792	673	503	299	283	0·587	0·556
DD_1	15	21·0	34·0	30·5	825	673	573	249	230	0·434	0·401
DD_2	15	20·9	29·7	27·8	820	673	499	254	237	0·508	0·474
DD_3	25	20·5	27·9	26·5	816	673	469	259	242	0·551	0·515
DD_4	10	21·5	27·5	26·4	811	673	462	266	249	0·575	0·538

APPENDIX I.

BEING A REPORT TO THE STEAM-ENGINE RESEARCH COMMITTEE, ON PREVIOUS PROGRESSIVE SPEED AND PRESSURE TRIALS.

By Professor DAVID S. CAPPER.

(11 *March* 1896.)

So far as the writer has been able to discover after an extended search through French, German, English, and American records, only three series of steam-engine experiments have been carried out at progressive speeds and pressures.

Peabody.—In the first series Professor C. H. Peabody experimented in 1884–5* with a single-cylinder non-condensing engine of the Harris-Corliss type at the Massachusetts Institute of Technology. The cylinder was 8 inches diameter and 24 inches stroke. The boiler pressure was kept nominally constant throughout at 70 lbs. per square inch above atmosphere. But in the several trials variations occurred between 68 and 75 lbs. per square inch. The cut-off varied from 1·29 to 14·8 per cent. of the stroke. The speeds adopted were 23, 31, 36, 49, and 50 revolutions per minute. Each trial lasted about $1\frac{1}{2}$ hour, and the water per indicated horse-power per hour was measured and compared with that shown upon the indicator diagrams.

Denton and Jacobus.—In 1888 Professors J. E. Denton and D. S. Jacobus made a more elaborate series of trials † of a simple non-condensing engine, with cylinder 17 inches diameter and 30 inches

* Transactions, American Society of Mechanical Engineers, vol. 7, page 328.

† Transactions, American Society of Mechanical Engineers, vol. 10, page 722.

stroke. The engine was built to drive one of the air compressors of the Rand Drill Co. Trials were run at 9, 11, 13, 17, 25, 60, 64, and 88 revolutions per minute, with a boiler pressure of 90 lbs. per square inch above atmosphere. The cut-off was not kept constant, but varied from one-eighth to half stroke.

A further series of trials with varying pressures was run at a constant speed of 60 revolutions per minute, the pressures being 90, 60, and 30 lbs. per square inch above atmosphere, and the cut-off varying from 5 per cent. to full stroke. The lowest consumption obtained was 27 lbs. of water per brake horse-power hour, and the highest 39 lbs. per brake horse-power hour.

Neither of the above series strictly furnishes examples of progressive speed and pressure trials with only one element varying at a time; and in neither case could condensing trials be made.

Willans.—The trials of the late Mr. Willans cover very fully the field of the Committee's proposed investigations. In 1887–8 non-condensing trials * were made with both simple and compound engines of the Willans type indicating up to 45 horse-power. Trials were made at 400, 200, and 100 to 120 revolutions per minute with the simple engine, and at pressures of 50, 70, 90, and 110 lbs. per square inch above atmosphere. With the compound engine trials were likewise run at each of the above speeds, and at pressures of 90, 110, and 130 lbs. per square inch above atmosphere. The ratio of expansion however was altered for different pressures, and varied from 2·174 to 4·8 expansions.

In 1891–2 a much more extended series of condensing trials † at different speeds was made with a compound engine. The speeds chosen were 400, 300, 200, and 100 revolutions per minute, with pressures of 180 to 35 lbs. per square inch above atmosphere. Sets of experiments with varying pressures at each speed were carried out with each of the following expansions—5, 10, 12·36, and 15·55. But the only series which was nearly complete, that is, where trials

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* Proceedings, The Institution of Civil Engineers, 1887–8, vol. xciii, page 128.

† Proceedings, The Institution of Civil Engineers, 1892–3, vol. cxiv, page 2.

at nearly all pressures were made for each speed, was with 5 expansions, the pressures being 130, 100, 80, 60, and 35 lbs. per square inch above atmosphere. The observations made were very complete, but no measurement of brake horse-power was attempted.

The proposed trials of the Committee therefore will cover much the same ground as those of Mr. Willans, but at lower speeds. They will however be made with a different type of engine; the cut-off should be kept constant throughout the whole of the experiments, condensing and non-condensing; and all results should be measured as a function of effective power,* so as to eliminate the serious uncertainty which attaches to indicator readings.

APPENDIX II.

MAIN DIMENSIONS OF HIGH-PRESSURE VALVES, &c.

(*See Fig.* 46, *page* 259.)

2 Expansion Plates, each $2\frac{5}{64}$ inches wide.
Throw of Main Valve Eccentric, $2\frac{1}{4}$ inches.
Throw of Expansion Valve Eccentric, $2\frac{3}{4}$ inches.
Angle of Advance of Main Valve Eccentric, 30°.
Angle of Advance of Expansion Valve Eccentric, 90°.
Length of Connecting-rod of Engine, 3 feet $10\frac{1}{2}$ inches.
Stroke of Engine, 14 inches.

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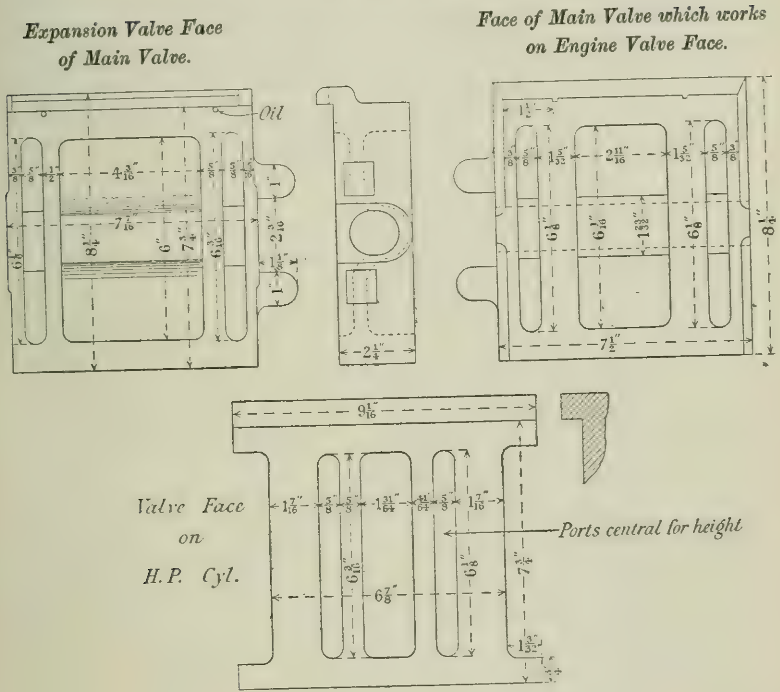
* In actual working it was found that at the lowest speeds and pressures the effective horse-power was so small that differences in lubrication of the brake blocks, etc., made a relatively large difference in the power. Moreover on some of these trials the large fly-wheel which was disconnected was found slightly to have touched the end of the shaft at one point, so that the brake horse-power was affected. The brake horse-power on these trials therefore has been omitted. After careful consideration and examination of the preliminary trials it was evident that at the lowest powers the specially calibrated indicators were giving records which were more reliable than those of the brake and spring balances, and it was therefore decided to express results in terms of indicated instead of brake horse-power.

FIG. 46.

Diagram giving dimensions of Ports.



Discussion on 17th March 1905.

The PRESIDENT said the members had met to hear the First Report to the Steam-Engine Research Committee by Professor Capper. This Committee was appointed nearly nine years ago, and then consisted of the following gentlemen:—Professors Kennedy and Capper, Messrs. Bryan Donkin, Longridge, Mair-Rumley and Maw. The present members of the Committee were Mr. Maw,

(The President.)
Professor Capper, Mr. Davey, Professor Kennedy, Mr. Michael Longridge, Mr. Mair-Rumley and Captain Sankey. He anticipated that the Report would be received with great attention, and would give rise to a good discussion. He thought that, from the applause that had greeted the reading of the Paper, the members would agree with him that a most hearty vote of thanks was due to Professor Capper for his able and most interesting Report.

The resolution of thanks was carried by acclamation.

Captain H. Riall Sankey, in opening the discussion, remarked that the author had said that Mr. Macfarlane Gray had called Fig. 48 a temperature-entropy chart; this was an error, he had named it the $\theta\ \phi$ chart. Professor Capper had suggested it should be called a heat chart, but in reality it was more than this so soon as the constant-volume lines were added, because the area between these lines gave the work done by or on the substance during transformation from one state to another, while the area between the adiabatics gave the heat change during the transformation. The author had explained (page 243) how the re-evaporation during the expansion could be exhibited on the chart, and it would be interesting to see how this actual re-evaporation compared with the theoretical re-evaporation. Willans in his Paper on Steam-Engine Trials * had shown how the theoretical re-evaporation line could be found. In Fig. 47, if A B were the initial temperature of the steam, and A_1 B_1 were the exhaust temperature, and the point C represented the dryness or quality of the steam at cut-off, the line C R would be the re-evaporation line required; it was a curve similar to the water line of the chart, inverted. It would be seen that the point R was approximately at the foot of the adiabatic drawn through B, and for most practical purposes a straight line drawn from C to the foot of the adiabatic was sufficiently accurate. This construction had been applied to Fig. 48, the point B being taken as the top left-hand corner of the leakage diagram, and the adiabatic had been drawn down to the exhaust temperature corresponding to the line A_1 B_1 in

* Proceedings, The Institution of Civil Engineers, 1892-3, vol. cxiv, page 2.

Fig. 47. The approximate re-evaporation lines were shown by the dotted lines in Fig. 48, and it would be seen that in the first case (trial DD_2) the actual re-evaporation line lay somewhat to the right of the theoretical at its lower extremity; in the second case (trial CC_2) the two lines were fairly close together; in the third case (trial BB_2) the actual re-evaporation line fell short of the theoretical at the beginning of the expansion, but it came up to it again at the

FIG. 47.

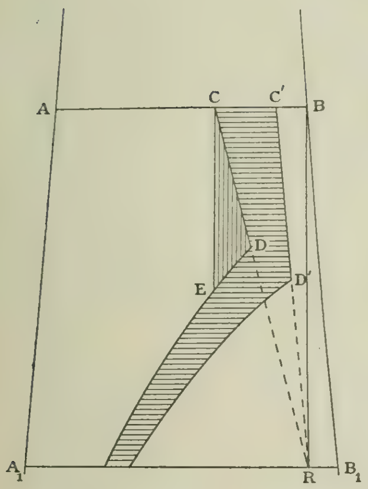
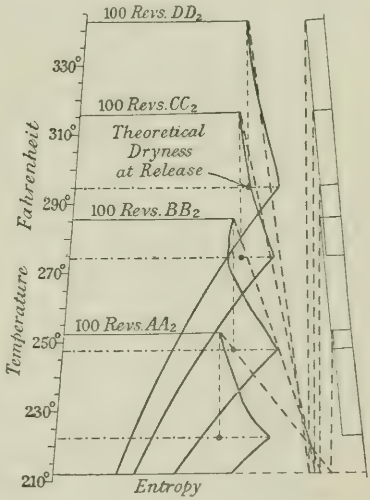


FIG. 48.

Temperature Entropy Diagrams.
Trials AA_2, BB_2, CC_2, DD_2 Unjacketed.
(*See Fig.* 24, *page* 201, *with dotted lines added.*)



moment of release. In the last case (trial AA_2) the actual re-evaporation was considerably less than the theoretical during the whole of the expansion. Strictly speaking, the actual re-evaporation should always be less than the theoretical, and in general it was so. In the present case, however, owing to the engine being worked with the same number of expansions for all the trials, the release pressure was high in the first two trials, causing a considerable drying action on the walls and assisting the re-evaporation. In trial AA_2,

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(Captain H. Riall Sankey.)

however, this drying action did not occur; there was obviously a considerable amount of water in the cylinder, and the re-evaporation was sluggish. As minor reasons, there was the leakage into the cylinder during expansion to be taken into account, this leakage would be greater at the higher pressures, as there would then be a greater drop of pressure in the cylinder during expansion. Lastly, the leakage correction was stated by Professor Capper to be somewhat too great, which would cause the point R to be situated too much to the left, and the error in the approximate method employed for drawing the theoretical re-evaporation line was in the same direction. It would be found that similar results to the above would be obtained by drawing the evaporation lines on Figs. 22, 26, 28 and 30 (pages 199 to 207). The construction shown in Fig. 48 (page 261) could also be applied to the jacketed trials, and it would be seen that in every case the re-evaporation extended far beyond the theoretical, more particularly so in the trials at low pressures, trial A_2 for instance. The reason was obvious: there was less condensation, and the heat from the jacket drew the expansion line more to the right. In the case of trial A_2 there was another reason—the steam had been considerably throttled, therefore eddies would be produced, and the energy in these eddies on reappearing as heat would have the same effect on the expansion line as if re-evaporation had taken place. The same remark applied to trial B_2 in a less degree.

Returning to Fig. 47 (page 261), if an adiabatic were drawn from C to cut the constant-volume line a triangle would be cut off (shaded vertically) which would represent the heat units gained by the re-evaporation. If the condensation had been less, as for example as represented by the point C′, the theoretical re-evaporation would have been less as shown by the line C′R, but the release would have been at a lower pressure on the assumption that the ratio of expansion was the same. Since the volume at C′ was greater than at C the point of release could be found by the intersection of the line C′R of the lower volume line shown in Fig. 47 at the point D′, and the area shaded horizontally represented the gain in heat units due to having less condensation. He thought that the above showed very clearly

that although a little good was obtained by re-evaporation, the way to get an economical engine was to reduce the condensation. (*See page* 276.)

Mr. Michael Longridge, Member of Council, was sure all the members would agree with him that the Report was a very difficult one to follow, and required more study than he and perhaps many other members had been able to give to it. He therefore proposed to limit his remarks to one point, namely the first of the author's conclusions (page 246) that leakage through the slide-valve, to the importance of which Messrs. Callendar and Nicolson had drawn attention, had been quantitatively determined under defined conditions, and had been shown to be nearly independent of speed of sliding surface and proportional to difference of pressure between the two sides of the valve. The leakage question had taken up a very large part of the Report, and he thought rightly so, because upon the acceptance or denial of the figures given depended the whole results of the Report. He did not wish to question the accuracy of Professor Capper's observations, but he would like to point out that the statement that leakage was proportional to difference in pressure was hardly confirmed by the measurements recorded in the Report. These showed that the observed leakages were nearly proportional to the square root of the difference of pressure. At a meeting some time ago he had occasion to speak of the theory of leakage, both of saturated and superheated steam, and he suggested that the velocity of flow through any leakage opening would, like the velocity of flow in any other case, be proportional to the square root of the head. He thought the curves on Fig. 32 (page 212) confirmed that view. These curves were practically parabolas, the leakage in the first case, namely, when the ends of the cylinders only were jacketed, being equal to 4·1 times the square root of the difference of pressure; and in the second, when the cylinders were completely jacketed, equal to 3·46 times the square root of the difference of pressure. He thought the curves were more reliable guides than the figures in the Report, because they eliminated the irregularities which the measured leakages showed. The observed leakages had been used to calculate Callendar

(Mr. Michael Longridge.)

and Nicolson's factor C which was equal to $\frac{\text{overlap}}{\text{perimeter}} \times \frac{\text{leakage per hour}}{\text{pressure difference}}$ and the results of the calculations were given in Table 5 (page 221). They varied by about 100 per cent., namely from 0·032 to 0·014. If in the above formula they substituted square root of pressure difference for pressure differences, they would find that the resulting values for C became practically constant, though of course differing from Callendar's value 0·02. That, however, was merely a question of formulæ, and not very important. The important point was whether such leakages as 20 per cent. actually did exist under ordinary conditions; and he must say that notwithstanding the evidence brought forward in the Report, and in Callendar and Nicolson's Paper, he could not believe it. He thought that in the present case the leakages were to a certain extent abnormal, because there was no current of steam passing through the steam-chest in which the valve worked. In that case a good deal of water would collect in the chest, would lie about the valves, and be gradually sucked in by the small leakage between the valve and its face; and whether the velocities varied as the square roots of the pressures or as the pressures, the quantity going through the leakage opening would be very much larger when the material going through was water than when it was steam, because the weight of a given volume of water was many times that of an equal column of steam.

In the Annual Report of the Council just presented it was stated that the question as to whether the research should be continued and, if so, in what direction, would be considered after the discussion of this Report. He sincerely hoped the work would be continued; and if he might do so without appearing to dictate to the Research Committee, he would use this occasion to suggest what the next step should be, so that members, having the needs of the Committee put before them, might be induced to assist in providing the necessary apparatus. In his opinion this leakage question barred the way to further progress and required further investigation; and the best way of investigating it would be, he thought, to have a number of valve-chests of various descriptions made, each chest to have a port leading into a chamber in which leakage might be collected, a valve —Corliss, piston, slide, or double-beat, as the case might be—with

sufficient lap to work without uncovering the port, and a nozzle at each end, with a flange to bolt to a steam pipe. Such experimental valve-chests, placed in circuit in a steam main supplying an ordinary engine, and experimented on with a current of steam always flowing through, would not only give evidence as to the extent of leakage but would show how leakage was affected by workmanship, and which kind of valve leaked least.

Mr. R. H. Willis thought that for purposes of reference it was handy to call the diagram to which Captain Sankey had referred a theta-phi diagram rather than a temperature-entropy diagram, and it was shorter to write. The remark applied perhaps almost more to gas-engine work than to the subject under discussion. It was just as handy to refer to for heat purposes as the ordinary indicator card was for power, but it was rather more difficult to plot. There was no question at all as to its value, and it seemed to be coming more and more into use. He thought the Report was quite an epoch-making one, and, as the author's results so far bore out Professor Callendar's, there was no doubt that the leakage question was the one which had to be considered. The most interesting point would be to see how it referred to piston-valves, because modern piston-valves had such very large surfaces relative to the surface in the cylinders.

Mr. Edward C. de Segundo said that there were many points in the Report which were highly suggestive, and which deserved very full consideration, and he cordially agreed with one of the speakers that it was impossible to discuss usefully such a Paper without having had more time to digest the contents thereof than had been afforded to members. Nevertheless, if he might be allowed to refer to one point in it, he would like to say that he was glad to see the author had tabulated the efficiency of the engine on the basis of the Carnot cycle as well as on that of the Rankine cycle. It savoured rather of heterodoxy to call into question the decision of the Committee which was appointed by the Institution of Civil Engineers to report upon the Thermal Efficiency of Steam-Engines, at the same time he could not help thinking that for the purposes of busy men, the Carnot

(Mr. Edward C. de Segundo.)

cycle was a very useful basis upon which to calculate the efficiency of an engine. He admitted that the Rankine formula more accurately represented the conditions under which steam was used in an engine, but although with high temperatures the discrepancy between the efficiency calculated on the Rankine basis and on the Carnot basis was very marked indeed—in the case of the gas-engine particularly so—still, after all, the Carnot cycle represented perfection of action between given temperature limits and was alluringly simple, whereas the Rankine formula strove to approximate to actual conditions but was decidedly complicated in comparison.

With regard to the theta-phi diagram, he would like to ask Captain Sankey if he (the speaker) understood correctly that in such a diagram the action of the boiler was taken into account as well as the action of the engine. It appeared to him that in the diagram they were dealing with the change of state of one pound of the working fluid through the whole cycle from the feed-water through the boiler, through the engine, and back to the feed-water temperature. Many people had a sort of idea that the theta-phi diagram was a sort of modification of the ordinary indicator diagram and that it referred only to the action of the steam in the engine, but that was not the case.

Captain SANKEY said it was not quite the case.

Mr. SEGUNDO said that that was an interesting point. He wished to be allowed to add his tribute of praise to that which had already been given to the author for his very interesting and important Paper; and to record his opinion, as a man who had some experience of experimental work, that it was quite impossible from a perusal of the Paper to form any adequate idea of the immense amount of time and trouble involved in obtaining and collating the results of the experiments, and for these reasons he thought Professor Capper and his assistants deserved the very hearty thanks of the Members.

Mr. Druitt Halpin exhibited a series of photographs and blue prints of an experimental engine at Montreal which had four cylinders. Several details were shown on Plate 6. One of the peculiarities of the engine was that the steam could work through the cylinders in any sequence, and that the cylinders could be worked jacketed or unjacketed, or that any ratio of expansion could be obtained. The angle between the cranks of the two engines could also be altered. Some of the principal parts of the engine were shown on the blue prints on the wall, but there was one peculiarity to which he wished to refer. An arrangement was shown on the first sheet by which the volume of the clearance was altered. The clearance could be altered from 1·2, the normal amount, up to 7·25 per cent., by variation of the position of the piston in the false clearance cylinder.*

The President thought the Report was so important that it would be better to postpone the discussion to an extra Meeting on 31st inst., which would give an opportunity to the Members, he was going to say to understand, but at any rate, to digest this very interesting Paper.

Discussion on Friday, 31*st March* 1905.

Mr. William H. Maw, Past-President, in resuming the discussion, said he was very glad to have the opportunity of saying a few words. In the first place, he emphasised the remarks of the President on the last occasion, as to the indebtedness of the Institution to the author for all he had done in connection with the Report. Everyone knew that when a man undertook the office of a Reporter to a Research Committee, he let himself in for a very large amount of work. But in the present case circumstances had arisen which rendered the labour quite exceptional. In the first place, as stated in the Report itself, the original programme laid down under the Chairmanship of Mr. Donkin had to be modified, in consequence of the Committee

* *See* Proceedings 1905, Part 1, page 82.

(Mr. William H. Maw.)
not obtaining the experimental engine which it was originally expected would be available. Professor Capper then came to the rescue by placing the engine at King's College at the disposal of the Committee, and it was necessarily felt that the rearrangement of the experiments must be left largely in his hands. Then when the researches were commenced, the author found great difficulty in consequence of the leakage through the valves, and that led him to carry out the very extensive series of experiments on valve leakage which were embodied in the Report. Those experiments involved an enormous amount of personal work to the author. Then the Committee, as the Members knew, lost the services by death of their friend Mr. Bryan Donkin, which again deranged the programme to a very large extent, and eventually it came to pass that practically the whole work of carrying out the experiments rested with the author, and the Report was essentially a one-man Report, that one man being Professor Capper. The Institution thus owed, he thought, an exceptional debt of gratitude to the author for the work he had so ably carried out. Last year, when the Committee resumed its meetings, and he (Mr. Maw) was elected Chairman, it was found that Professor Capper had accumulated an enormous amount of data, and it was the duty of the Committee not to arrange the experiments, but, in consultation with the author, to determine how much of that experimental data should be published. The Report, as the Members had seen, was a very extensive one, and dealt with an enormous number of experiments, but it only represented a very small amount of the information which the author had collected. He thought that no one, except perhaps the Members of the Committee who had had the opportunity of going through the whole of the original documents, had any idea of the amount of work that had been expended in obtaining the results laid before the Members in the Report.

Reference was made at the previous meeting to the fact that in the last Annual Report of the Council, it was stated that the future of the Steam-Engine Research Committee depended largely upon the results of the discussion on the Report now before the meeting. It thus followed that the Report should be discussed from two points of

view; first, from what he might call the author's point of view, namely, a discussion of the facts set forth in the Report, and criticisms on them—and he was sure that nothing would delight the author of the Paper more than that they should be very fully and thoroughly discussed—and secondly, a discussion from what he might call the Committee's point of view, that is, an expression of opinion as to the way in which the work of the Research Committee could be best carried on in the future. The Report, extensive as it was, practically only touched the fringe of the great subject of Steam-Engine Research. Apart from the experiments on valve-leakage loss, which formed such an important portion of it, it consisted really of experiments on the high-pressure half of the engine at King's College, and of that half used only as a non-condensing engine. It thus by no means exhausted the amount of information which might be obtained from that particular engine, while it left quite untouched the further information that could be obtained from similar experiments carried out on engines of larger size.

In speaking of the leakage experiments at the last meeting, he thought Mr. Longridge rather threw doubt on the absolute accuracy of a leakage of 20 per cent. being possible in the slide-valves. He thought for the moment Mr. Longridge had overlooked the fact that that loss of 20 per cent. took place when the engine was being worked at an exceptionally low power, only $\frac{7}{8}$ H.P., and the consequence was that the leakage, which was almost a constant leakage per hour under a certain pressure, then formed a very large proportion of the whole steam used in the engine. If reference was made to the results recorded in Table 13 (pages 252–253), it would be found that for the A series of experiments the difference between the steam passed through the cylinders per hour, and the steam per hour after deducting the leakage, was almost exactly 10 lbs. in all cases. That 10 lbs. formed a very large percentage in the case of the low-power trials, and was roughly about 20 per cent. In the A_5 trials, that leakage (which was just about the same in that case per hour) was only about $3\frac{2}{3}$ per cent. He thought at the moment Mr. Longridge did not take that particular fact into consideration. Mr. Longridge had rather doubted whether experiments on valve

(Mr. William H. Maw.)

leakage conducted in what he might call a dead end, without any flow through the chest containing the valve, were quite to be depended on. It was a matter which he himself had at first had some doubt about, but looking at the experiments he felt bound to say that those doubts had disappeared He thought the experiments, with some trifling exceptions, were very consistent, and it did not seem as if, with proper drainage of the steam-chest, the fact of there not being a flow through was any disadvantage.

There was one thing in the leakage experiments that had struck him as rather remarkable, and he would like the author to kindly say a word or two more about it in reply, namely, the very marked difference between the leakage with the valve lubricated and the valve not lubricated. Where there was a flow of steam through a steam-chest, it was not difficult to get a fairly good distribution of the lubricant over the valve, but where the valve was working in the steam-chest, without any flow, it seemed to him difficult to get the lubricant distributed over the valve-face. The fact that in the particular series of experiments under discussion there was such a very marked difference between the lubricated valve and the non-lubricated valve, showed that somehow or other the lubrication had been effectively realised and he would like to ask the author kindly to say how the lubrication was arranged.

There was another question he would like to direct the author's attention to, namely, the question of the steam through the jackets. He thought perhaps it would be a desirable addition to the Table 13 (pages 252–253) if the pressure in the jackets during each series of experiments was stated. He thought it had been given in some of the original papers, but it was not stated in the Report as published, and he thought the information had better be supplied. Apparently there was rather an exceptional amount of steam used in the jackets in the case of Experiment A_1, namely, 44 lbs. per hour, while in the next experiment, A_2, it was only $14\frac{1}{4}$ lbs.; 44 lbs. seemed rather an exceptional figure, but there might be some reason for it. He wished especially to draw the attention of the Members to Fig. 45 (page 249), which, he thought, was one of the most valuable diagrams they had ever had put before them. It summarised the author's deductions in the most admirable way.

Passing to what he might call the Committee's view of the Report, he would like to say—it was merely an individual opinion, not the opinion of the Committee, because he had not had an opportunity of consulting them—that the Report now under consideration pointed to the desirability of amalgamating the Steam-Engine Research Committee with the Steam-Jacket Committee. As the members knew, a Committee of the Institution had been in existence for some years dealing with experiments on steam-jackets, and he believed that a further Report from the Committee would be forthcoming in the course of a few months. After that Report was issued, he thought it would be well worth the consideration of the Institution whether the two Committees should not be amalgamated. The work of the two Committees overlapped in a number of points, and he thought it would be difficult for them to carry on their work independently without a considerable waste of time and energy. That was a point upon which Mr. Davey, who was the Chairman of the Steam-Jacket Committee, might like to say something later.

Then the question arose as to the future of the Steam-Engine Research Committee As he had already said, the Committee had only just touched on one very small portion of the researches open to them, and it was quite evident that the resources of such a Committee, as it at present existed, were not equal to carrying out a thorough series of researches in anything like a moderate time. He therefore thought it was open to question whether they should not endeavour to enlist the assistance of some workers who had other experimental engines available, and see whether they could not arrange for some simultaneous series of organized experiments to be carried out, which should be submitted to a Central Committee for consideration. There were a number of experimental engines in the country, and if they could get the gentlemen in charge of those engines to carry out, independently, different branches of research, the whole operations of the Committee might be very greatly shortened.

Mr. C. E. Stromeyer said he would like to touch on the point last raised by Mr. Maw, and to ask whether it would not be possible

(Mr. C. E. Stromeyer.)

to continue the trials on a large scale. He felt sure that some manufacturers would be willing to lend their engines for such purposes. Some experiments on very large marine-engines had already been carried out by Sir John Durston and Mr. Oram. They were tried with and without jackets, from 8,000 up to 19,000 I.H.P., and the results were that for the low power the non-jacketed engine had an advantage of 1 per cent. in the steam consumption, and for the high power an advantage of 5·6 per cent. With regard to the present Report, he wished to say that he had come to the meeting to inquire why it was that piston-leakage experiments were carried out on the lines indicated on page 222. He had gone very carefully into the diagrams, and plotted a continuous diagram of the weight of steam in the blocked end of the cylinder, which only received it by leakage, and the results were very unsatisfactory. He found that when the pressure on one side of the piston was about 105 to 106 lbs., then the weight of steam in the blocked end of the cylinder was gradually diminished, which would make it appear as if there were a flow of the steam from the low-pressure towards the high-pressure. That diminution of weight continued to the end of the stroke, and then, when the leakage should be from the high-pressure in the blocked end into the exhaust, and when a decrease of weight should have occurred, there was a steady increase. He thought that there must have been leakage from the blocked end to the atmosphere. Some steam seemed to have got away and got back again. It therefore did not seem to him that this particular method was an accurate one for determining what the amount of piston-leakage was. The calculated steam weights and losses were given in Table 15 (page 274).

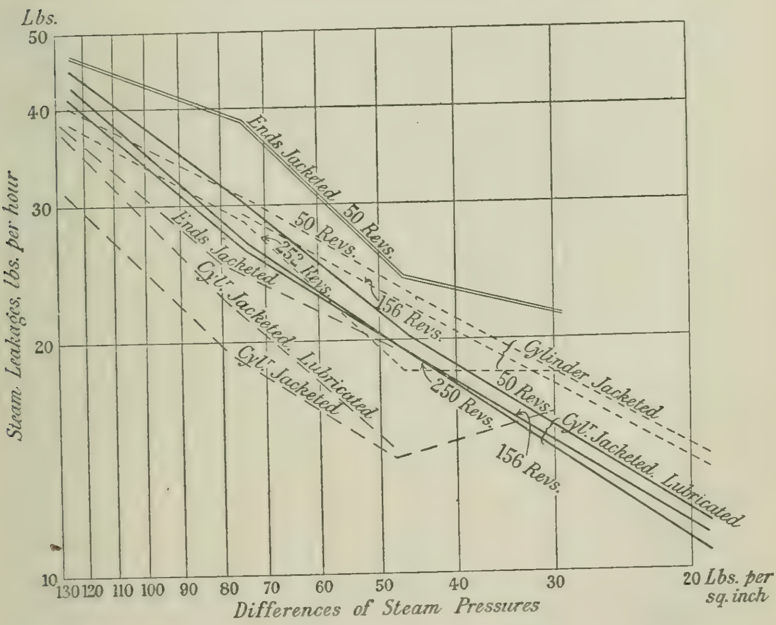
He had also gone very carefully into the figures which the author had given for the slide-valve leakage, and these he had plotted on a logarithmic diagram, Fig. 49 (page 273). The results were very consistent, except that the experiments at a pressure at about 29 lbs. seemed to be wrong. The figure showed that the leakage was not directly proportional to the pressure, but to a small power of the pressures; thus, in the case of the unlubricated jacketed cylinder, he found the power to be 0·553. If the leakage had been steam or water, then the index should have been $\frac{1}{2}$, which meant that the

flow should have been proportional to the square root of the difference of pressure of the steam on the one side and on the other. In the case just mentioned, it was slightly higher than that, it was 0·553, and the coefficients for that particular engine for the three speeds were 2·8, 2·7, and 2·6 lbs. per hour.

In the case of the jacketed and lubricated cylinder, he found that the index was 0·72, and the constants were 1·35, 1·25, and 1·15

Fig. 49.

Logarithmic representation of Results shown in Tables 1 and 2 (page 210). The abscissæ and ordinates have been marked from a slide-rule.



lbs. per hour. The diagram also showed that the two leakages overlapped, and that at the low speeds the lubricated slide-valve certainly had the advantage; it did not allow so much steam to pass as the unlubricated slide-valve, but for the higher pressure the lines crossed, showing that reverse results were obtained. He noticed that the quantities estimated from the leakage experiments

(Mr. C. E. Stromeyer.)

TABLE 15.

Position of Crank.	Steam Pressures in open Cylinder End.	Blocked Cylinder End.			
		Steam Pressures.	Differences.	Steam Weights.	Flow per $\frac{1}{24}$ Revolution.
	Lbs. per sq. inch.	Lbs. per sq. inch.	Lbs. per sq. inch.	Lbs.	Lbs.
0+24	105	12	+93	0·0095	+0·0006
1	106	13·0	+93	0·0101	−0·0001
2	106	13·5	+92·5	0·0100	−0·0001
3	106	14·2	+91·8	0·0099	−0·0004
4	105	15	+90	0·0095	−0·0005
5	103	16·3	+86·7	0·0090	−0·0008
6	86	17·5	+68·5	0·0082	−0·0010
7	70	19	+51	0·0072	−0·0013
8	60	20·8	+39·2	0·0059	−0·0014
9	53	22	+31	0·0045	−0·0013
10	48	23	+25	0·0032	−0·0010
11	45	23	+22	0·0022	−0·0003
12	?	23	say −5	0·0019	+0·0002
13	18	22	−4·0	0·0022	+0·0006
14	18	19·6	−1·6	0·0028	+0·0009
15	17	17·5	−0·5	0·0036	+0·0010
16	17	16·3	−0·7	0·0047	+0·0012
17	17	15·5	+1·5	0·0059	+0·0010
18	17	14·6	+2·4	0·0070	+0·0009
19	16	14	+2·0	0·0078	+0·0007
20	16	13·3	+2·7	0·0085	+0·0006
21	16	13	+3·0	0·0091	+0·0002
22	18	12·5	+5·5	0·0093	+0·0001
23	29	12	+17·0	0·0094	+0·0001
24	105	12	+93	0·0095	—

had been deducted from the power trials, and he feared that this had not been done to the best advantage, and different results might be arrived at if his figures were adopted.

He might perhaps refer to another difficulty which he did not notice the author to have dealt with, except to mention it, namely, the lag of the indicator drum and other imperfections of the indicator. A Paper * was read by Mr. A. W. Brightmore before the Institution of Civil Engineers in 1885, and he (Mr. Stromeyer) subsequently read a Paper † at the Institution of Naval Architects in 1894, dealing with the question of the lag of the indicating cylinder, and in his case he came to the conclusion that for an indicator string of about 5 feet, one ought to allow about $\frac{1}{8}$ inch at the end of each diagram, that is, the starting ends of the diagrams should be lengthened $\frac{1}{8}$ inch. According to Mr. Brightmore's Paper, it would be seen that the correction depended very much on the number of revolutions and on the weight of the indicator drum, and various other matters. In his own Paper he had plotted down on a continuous diagram the weight of steam that was in the cylinders, and he noticed that during the expansion period, when of course the weight of steam should be constant, there was always a slight rise. That slight rise was evidently the difference resulting from re-evaporation and leakage of the steam into the cylinder less the leakage into the exhaust port and past the piston; but seeing that there were four factors which affected the curve, it was quite impossible to use it for the determination of any one of them separately.

Captain H. Riall Sankey apologised for again taking part in the discussion, but he had been asked to describe some experiments on the leakage of piston-valves and piston-rings which he carried out in 1897 and 1898. The experiments on piston-valves were made with a small Willans engine, a partial section of which was shown in Fig. 50 (page 276). It would be seen that there were no pistons

* Proceedings, The Institution of Civil Engineers, 1885–6, vol. lxxxiii, page 20.

† Transactions, Institution of Naval Architects, 1894, page 407.

(Captain H. Riall Sankey.)

FIG. 51.

Leakage past Piston- and Slide-Valves.

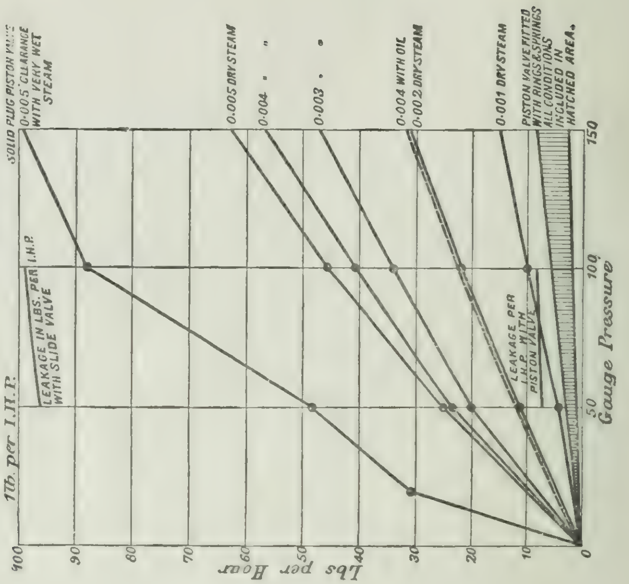
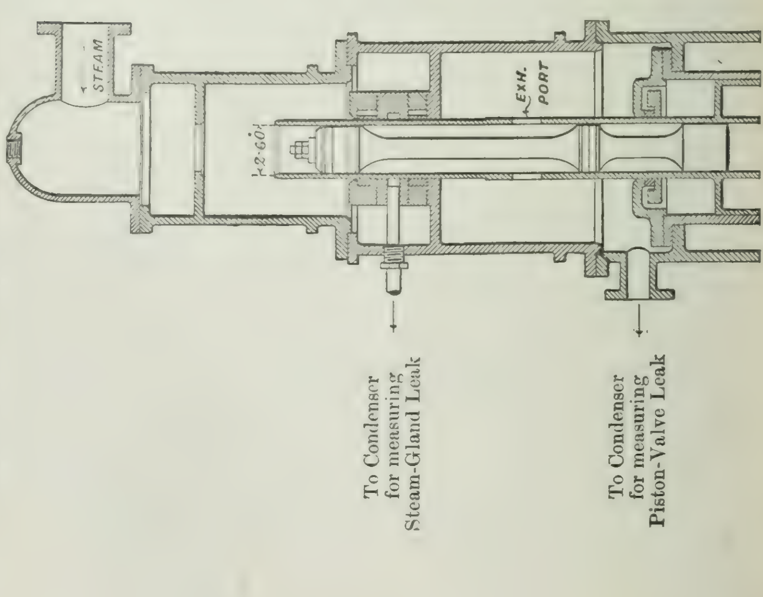


FIG. 50.

Arrangement for measuring Leakage past Piston-Valves.



fitted; there was only the hollow trunk, in which the piston-valve worked, and the arrangement was made to reciprocate at any desired speed by means of an electric motor. The object of the experiments was to determine the leakage past the piston-valve and past the steam gland surrounding the outside of the trunk. The trials were made with the engine standing and also running at revolutions varying from 20 to 500. When the engine was standing the leakage was erratic, but as soon as it revolved there was practically no difference in the leakage, whether the speed was 20 revolutions a minute or 500, which, it should be noted, agreed with Professor Capper's results. With the standard Willans valve, consisting of two spring rings separated by a dummy, the dummy having a clearance of about $\frac{2}{1000}$ of an inch, the leakage was found to be very small, as shown by the lower boundary of the shaded area in Fig. 51. The dummy ring was then made smaller so as to get a greater clearance; the split between the rings was made larger so as to get a greater leak in that way, and the splits were placed in prolongation instead of opposite each other. These various changes singly and combined increased the leakage, but not seriously, since in every case the leakage was within the shaded area.

The standard piston-valve was then replaced by a solid plug valve, made as tight as it would run without seizing, namely with a clearance of about $\frac{1}{1000}$ of an inch; and the leakage found was given in Fig. 51. Each of the black spots was the mean of several readings. Then the plug valve was ground $\frac{1}{1000}$th inch smaller, making a clearance of $\frac{2}{1000}$ths, then another $\frac{1}{1000}$th, making a clearance of $\frac{3}{1000}$ths inch, and so on. It was found that the leakage at all pressures increased almost proportionately with the clearance, when the experiments were with dry steam, as would be seen from Fig. 51. On one occasion a considerable amount of oil was put into the engine when the clearance was $\frac{4}{1000}$ths inch, and immediately the leakage dropped to what was shown by the dotted line, namely, about the same as with $\frac{2}{1000}$-inch clearance, which answered a question put by Mr. Maw (page 270). A coil was placed in the steam top through which water could be passed. In that way a portion of the steam was condensed, so that there was a shower of rain coming down on to the

(Captain H. Riall Sankey.)
piston-valve. The leakage was much increased, as shown in Fig. 51, for the case where the clearance was $\frac{5}{1000}$ths inch. The leakage was also tried with water, by forcing it in with a pump, and in that case the leakage was enormously increased, being from 8 to 16 times as great as with dry steam in corresponding cases. The leakage of the steam-gland was also measured. It was found that the results were not so consistent as with the piston-valve, probably because water would form on the top of the gland-box and be forced through in gulps; but on the average the leakage of the gland was about $2\frac{1}{2}$ times greater than that of the piston-valve in the corresponding cases, which fairly corresponded to the differences in dimensions.

He had calculated the factor C given in the Report, and found that for the standard piston-valve (lower line of shaded area) it was 0·003, which was $\frac{1}{7}$th less than the factor the author had found with a slide-valve. The author's factor corresponded almost exactly with the lowest leakage line for the plug-piston ($\frac{1}{1000}$-inch clearance). He had also worked out what the leakage would be expressed in lbs. per I.H.P. per hour with Professor Capper's slide-valve and with the standard piston-valve, calculated on the normal speeds of the respective engines, and the result was given in Fig. 51 (page 276), from which it would be seen that the latter was about $\frac{1}{10}$th of the former.

He next referred to experiments made to determine the leakage past piston-rings. The apparatus was shown diagrammatically in Fig. 52, and it consisted of a small Willans engine driving a dynamo, in which the usual steam distribution by means of the central valve was replaced by a D slide-valve, as shown. Experiments were made with mean pressures varying from 4 lbs. to 46 lbs. per square inch. Obviously the leakage past the piston-rings would find its way into the space marked B, and carried by the pipe F to the condenser D, so that there was quite an easy means of finding the rate of leak past the piston-rings. The trials were made at various speeds, and it would be observed that so far as leakage was concerned the piston-rings were working under normal conditions. The first trial was made with the standard rings in a cylinder of 10 inches bore. Those rings, when free, expanded one-tenth of an inch; the result was the lower leakage line marked B in Fig. 53 (page 279), in which mean

Fig. 52.—*Apparatus used for measuring Leakage past Piston.*

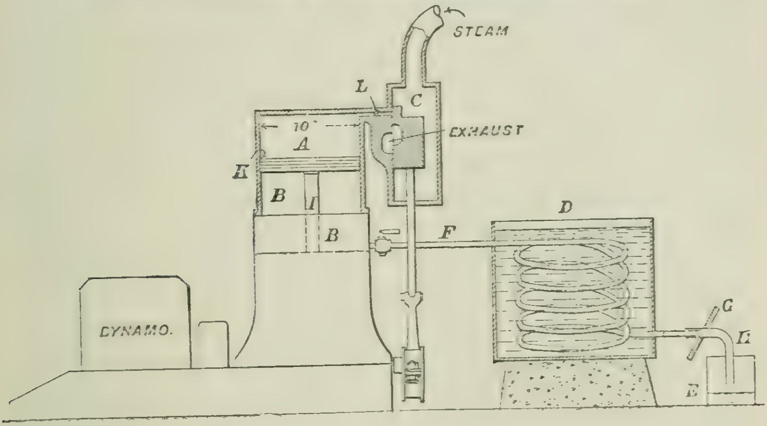
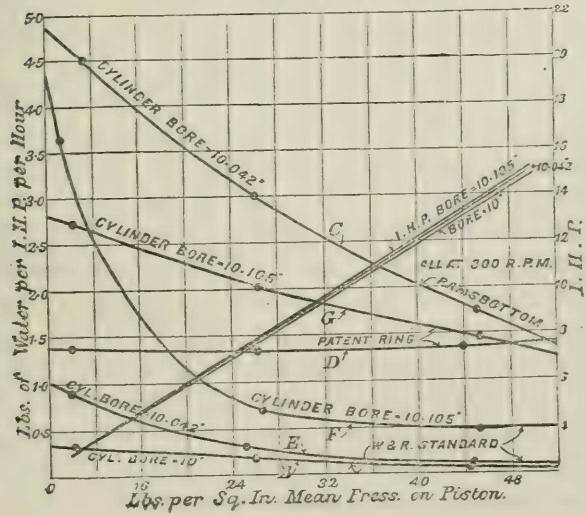


Fig. 53.—*Leakage past the Piston.*



x 2

(Captain H. Riall Sankey.)
results for the trials at 500 revolutions were expressed in lbs. of leakage per I.H.P. per hour, plotted on a mean pressure base. Then the cylinder was bored out approximately $\frac{4}{1000}$ths of an inch, and the leakage was slightly increased (curve E). Some patent rings, which had been sent for trial, were next tried before the cylinder was bored out again ; these rings were the correct size for the bored-out cylinder. The leakage was far greater than with the standard rings (see leakage line D).

The cylinder was next bored out to 10·105 inches. In that condition the standard rings were just a fit in the bore, and were fully expanded; it would be seen the leakage was considerably increased (leakage line F), especially at very light loads, the reason being that the rings were steam-packed, and when the load was very light there was not sufficient steam to pack them. The leakage with the patent rings was given by line G for this larger cylinder, and line C represented the result with a single Ramsbottom ring; the piston body was not sufficiently deep to admit of more than one ring, so that the leakage line was not a fair representation of the leakage when there were two or more Ramsbottom rings.

Mr. VAUGHAN PENDRED thought the Report was so full of matter for discussion that, instead of occupying ten minutes, he could speak about it for two or three hours. The first point to which he wished to call attention had been raised to a certain extent by Mr. Maw, namely, the future of the Steam-Engine Research Committee. He did not want to say anything which was severe, or which could be regarded in the slightest degree as personal, but a question he wished to ask was: What was the value of the Report under discussion? He saw around him a very large number of young men, most of whom hoped the time was not very far distant—and he hoped so too—when they would be called upon to design something in the way of an engine: either a mill engine, an electric-light engine, or a marine engine. He could not imagine any of the members sitting in a drawing office, turning to the Report, and seeking successfully in it for information which would be of use to them. He fully endorsed everything that had been said in regard to the author and the work

he had done. He (the speaker) had had in one way or another nearly fifty years' experience of the steam-engine in all possible forms, and engineers had the results of hundreds or even thousands of experiments that had been carried out. The literature of the subject was enormous, but he did not believe anybody had done better experimental work than that which the author of the Report and his assistants had accomplished. But what did it all come to? It was not the fault of the author, or of the Research Committee, or of any engineer, that an inquiry of such a kind must be futile; it was the fault of the steam-engine. Every steam-engine was a law unto itself. If the clearance space and the conditions generally of the engine with which the author had been working were altered, an entirely different set of results would be obtained.

If any of the members would take the trouble to go into the library of the Institution, they would find on its shelves the Transactions of the American Society of Mechanical Engineers. He wished to draw particular attention to a Paper in those Transactions on the "Promise and Potency of High-Pressure Steam," * illustrated by the triple and quadruple expansion experimental engines at Sibley College, Cornell University, by Professor Thurston. He also wished to call attention to another Paper in the Transactions of the American Society, namely, "The Laws of Cylinder Condensation," † by Arthur L. Rice. Nothing more elaborate and nothing more careful had ever been carried out than those particular experiments. Thurston's Paper was a splendid treatise on what went on inside an engine. Going back over the history of the steam-engine, it would be found that almost as far back as the memory of man went the merits and demerits of the jacket had been discussed. One man said that jackets ought to be used and another man said they ought not; and in their arguments in connection with them they resorted to nearly everything short of bloodshed. But the result was that, after all the investigations and discussions which had taken place, engineers were in precisely the same position now as they were in those earlier times.

* Transactions, A.S.M.E., 1897, page 160.

† Transactions, A.S.M.E., 1897, page 950.

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Going back 32 or 33 years, they had the trials made of portable engines by the Royal Agricultural Society when the racer was built. The racer was a very remarkable engine in that it was built for a particular purpose, and was made the subject of the most elaborate investigations. He only wished that his old friend Sir Frederick Bramwell could have been present and told the members what he knew about it. At the time the speaker happened to be brought intimately in connection with the subject, because he had some very close personal friends who built racers. A racer had to be built 6 or 12 months before the time of trial; the engine had to be placed in a special shed, and worked by a special staff, and every possible effort was made to get the highest possible result out of it. What was the result sought for? The competitor declared when he came to the trial at the Show ground what power his engine was going to work at, the number of revolutions and the brake load; 14 lbs. of coal were allowed per declared horse-power, and the engine that was able to run for the longest time won the prize. Nearly all the engines were fitted with jackets, so that steam could be turned into them if necessary. If the members referred to the Journals of the Royal Agricultural Society, it would be found that not one single engine which admitted steam into the jacket during a competition had taken a prize. Taking the case of the Reading Co.'s engine at Cardiff and also the case of Paxman's compound engine at Newcastle-on-Tyne, they were tried first for long periods with steam in the jacket, and out of the jacket; and the winning engines in the show-yard did not take steam into the jacket. That was equally true with 50 lbs. and with 80 lbs. steam.

He intended to have said something about slide-valve leakage, but he had time only to ask one question about it, which perhaps the author could answer. A good deal was heard about the water. He wanted to know what that water was supposed to represent. If it came from the boiler as steam, and condensed in going under the valve, that steam had to leave its heat behind it in the engine in some way. They certainly could not for a moment regard the loss of water under those circumstances from the same point of view that the loss of steam would be regarded. He simply asked that question

for information. The question of evaporation and re-evaporation had been raised, and unless the Paper was read very carefully, it was slightly confusing. The point was apparently missed that whatever went into the cylinder of a steam-engine as steam must leave it as steam, and whatever went into it as water must leave it as water. There was no getting away from that fact under any possible circumstances. Supposing that the re-evaporation did not equal the condensation, then the cylinder would keep on getting hotter and hotter and storing up heat until condensation ceased. Thurston remarked in the course of one of his Papers, "The exhaust steam contains precisely the amount held in suspension on entering the valve chest, plus the condensation due to waste by external conduction and radiation and its conversion into work." Supposing for a moment that the whole heat coming into a cylinder was 100; supposing that the radiation was 10, and that that due to the performance of work was 10, the re-evaporation would be 80; the rest would go out of the cylinder as water. There was no getting away from it; it was impossible to elude the question in any shape or form; it was a physical fact that must hold good. As for the distribution of the periods of re-evaporation, whether during expansion or exhaust, that was quite another affair, and an extremely variable quantity. In that connection he might cite many experiments that had been carried out, as for instance those on the Pawtucket pumping-engine,* which were to be found in the Transactions of the American Society of Mechanical Engineers. It would be found that the quantity re-evaporated was exceedingly variable, and sometimes ridiculously small.

Not a word had been said in the Report with regard to the effect of radiation and conduction from the cylinder itself. One of the standing arguments that had been raised against the jacket was that the surface was so far increased that radiation and conduction represented a very considerable loss of heat. Taking an engine when it was working to $\frac{9}{10}$ths of 1 horse-power or something like that, the surfaces, the heat and the temperature were the same as

* Transactions, A.S.M.E., 1890, page 328.

(Mr. Vaughan Pendred.)

when very much more power was developed; what was the loss by radiation? In an ordinary engine an engineer would say he could neglect that; but in carrying out scientific experiments it was just as well to have the results accurate.

There was one remark he wished to make in conclusion. The Paper contained a series of experiments which gave particular results, and the author had reasoned from them that it was possible to get precisely the same results with another engine. If this was not true, then the Report had no general application. Before sitting down he would cite two cases to show what the probabilities were; and Captain Sankey could correct him on one if he was in error; and Mr. Davey could correct him on the other. If his memory was correct, Mr. Willans in a Paper read before the Institution of Civil Engineers cited a memorable and noteworthy case in which a quantity of water equal to about one tablespoonful lodged in the bottom of a cylinder and made a most material difference in the whole performance of the engine. The other instance was that of a very large pumping-engine at Staveley put up by Mr. Davey, which had a 10-foot stroke, and a 72-inch low-pressure cylinder, pumping at one lift 812 feet. That engine did not make the number of strokes in a minute it was required to make under the contract, because the cylinders were not fitted with drain cocks. Drain cocks were fitted to the engine—there was no other difference that he was aware of—and the engine then ran something like 2 strokes a minute over its contract number. It would thus be seen that very small details made enormous differences in the performance of an engine. The fatal difficulty with all research questions from the beginning to the end was that what was true of one engine was not necessarily true of any other engine, and was probably not true of it at all.

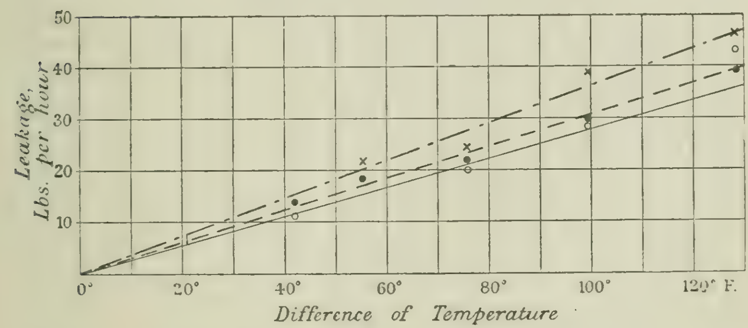
Professor F. W. Burstall said it was a particular source of gratification to him to speak on the Report, for the simple reason that the research was commencing when he was an assistant of the author's, and he knew to some extent what was in Professor Capper's mind at the time. He considered that a Paper of such a kind was

quite inadequate for discussion anywhere, there was such an immense amount of information that it would take one quite a considerable time to fully digest the whole of it. He proposed to deal with the subject which seemed to have attracted a good deal of attention, namely, that of leakage through the valves. He need hardly say that it was a most important question. The last speaker had asked how far such things influenced the question of the design of the engine. He should say it meant everything. If Professor Capper's Report, and the Paper of Professors Callendar and Nicolson were to be trusted, all valves leaked, whether they were slide-valves or

Fig. 54.

Slide-Valve Leakage varying with Temperature.

(Compare Fig. 32, page 212.)



Corliss valves, and although they did not say so, double-beat valves, such as were in use in the Sulzer and Cornish engines. The members had no information about that. If there was a definite law of valve leak, he thought it was of the highest importance that the engine designer should know what that law was, because it would help him very considerably in his design. He was afraid he could not see that the experiments of Callendar and Nicolson proved that there was a definite law of valve leak, that was to say, it was either proportional to the difference of pressure, or proportional to the overlap. He had taken the figures out in every form: he had plotted the leakage against the pressure as it was given in the Report, and then as against the temperature, Fig. 54, and the curious

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thing was that when the valve leak was plotted against the difference of temperature between the valve-chest and the exhaust, the points lay upon a straight line, that was, taking the whole number of experiments given in the Report. He would be sorry to have it thought that that was in any way universal. The number of experiments in the Report were not sufficient to warrant one in stating a law. Before stating a law of valve leak, it would require an immense number of experiments before one could justify the fact that the valve leak was proportional to the difference of temperature between the valve-chest and the exhaust. But it was worth while to consider what were the consequences if it was proportional. He took it that, if the leak was proportional to the difference of temperature, it rather pointed to the leak being due to a distorted valve. Those who had experimented on slide-valves, working first with saturated and then with superheated steam, would have noticed that when they took the flat valves out and tested them for truth after experiments on the superheated steam, that they had invariably warped. That was a practical fact. If that warping took place with superheat, and was apparent when the valve was cold, why should they deny the fact that it was possible the valve warped and returned to its shape when it became cold, even when dealing with saturated steam? He thought Captain Sankey's experiments definitely went to show that a warping valve was the cause of the leak, because if the members would notice, his experiments were made on Willans engines, with spring rings. If there was one form that was less susceptible to warping than anything else, it was a purely circular form. The slide-valve was a more or less complex casting, in which there were initial stresses which might or might not be released by the action of the steam, whereas with the spring ring none of those conditions existed. Captain Sankey's diagrams went to show that the spring ring gave a very much smaller coefficient, 0·003, as against 0·21 in the case of the flat valve. He would be sorry to have those things carried too far, because he was perfectly well aware that Professor Capper would say at once, "How do you account for it that engines with flat valves do as well, or even better, than those with piston-valves?" Which of course was a perfectly

straightforward answer. In fact the actual tests showed most distinctly that engines with almost any kind of valve would do as well as those with any other, proving that it was not altogether a question of valve leak that affected the economy of the engine.

He should like to say, in agreement with Mr. Maw, that he did not think the vexed question of valve leakage, the effect of speed, and the many problems which depended on so many simultaneous factors, would ever be determined by one single individual. It was only by co-operation of those people who had engines at their disposal, and who could make really accurate tests, that the work would be carried out. If those people placed their material at the disposal of the Steam-Engine Research Committee, he thought something like laws might be arrived at which were independent of a particular engine; and, speaking personally, he should be only too pleased to put any of his engines at the disposal of the Committee.

Apart from that, the particular point to which he wished to direct attention was the question of the dryness-fractions mentioned on page 228. It would be noticed that the dryness-fractions were given in the last column on that page, as if the expansion from cut-off were adiabatic. Perhaps the author would be good enough to tell him before he made a mistake, whether the steam at cut-off was taken free of leakage, or whether the leakage had been deducted.

Professor CAPPER stated that it was taken free of leakage.

Professor BURSTALL said he understood it was the gross feed.

Professor CAPPER replied in the affirmative.

Professor BURSTALL, continuing, said that if the members considered the gross feed there, they would see that even in the unjacketed trials a very considerable amount of re-evaporation was obtained. Taking the previous column, that is, the actual dryness-fraction obtained by deducting leakage, in some cases it would be found the steam was superheated at the jacketed trials. That struck him as a curious result. He did not say it was not correct, because

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he had made sufficient experiments with steam-engines never to be surprised at anything he got; but he did consider that dryness-fractions varying from 1 down to the last figure, 0·69 in the case of the full load unjacketed trials, showed extremely dry steam; and it would be interesting to know whether any experiments had been made to determine what the wetness of the steam was before it entered the cylinder at all. Of course such experiments were very difficult to make, and the results were perhaps not very reliable; but still, granted that it was a locomotive boiler, which he believed it was, and the length of steam-pipe to the boiler of the engine was something like 40 feet, his experience of experiments on locomotive boilers and long steam-pipes was, that the steam would initially contain something from 5 to 10 per cent. of water, and he did not quite see how it could get so dry as 1, taking it that the leakage was accurate.

Mr. Pendred (page 282) alluded to a point as to how the steam passed away in the form of water with regard to giving up its heat. That was a point that had greatly troubled him. The steam was supposed to condense on one side of the slide-valve, which passed as water to the exhaust slide—he was speaking generally—and there it re-evaporated. Looking at the problem physically, he did not see why the steam should condense, to begin with, and in the next place that heat had to be conducted from the steam side to the exhaust side, in order to provide the heat necessary to re-evaporate that water into steam in the exhaust. Why should the heat travel along the slide-bar at all? There was very little difference of temperature from a conductivity point of view, and physically speaking he could not see why that heat should travel along the bar at all. Therefore, if the steam leaked through, he could not see why it should go through as water and not as steam. Of course the reason for taking it as water and not as steam was, that if the velocities of dry steam passing through were calculated, figures were obtained which were wholly absurd, and therefore they must say that, if it leaked at all, it leaked as water. At the same time he did not feel satisfied that the valve leakage had been made out to be a definite law, on which engineers could rely, with any description of engine. What

engineers really required now was a series of experiments, not necessarily made on an engine cylinder, but made to determine the law of leak in valves of all forms, and valves of different materials. All the present experiments had been made on cast-iron, which was a notoriously warping material. He would suggest that, if possible, experiments should be made on cast-iron valves, on cast-brass valves, and on a forging, and see whether the result was due to distortion, or whether the steam really flowed as a water film. He did not think there was anything more important for the steam-engine makers in this country, than to receive from such a great Institution as the Institution of Mechanical Engineers, some definite information about which there should be no shadow of doubt, as to what law they were to follow in designing valves, and what the valve leak would be.

Mr. A. L. Mellanby thanked the President for the privilege of allowing him to address the meeting, and also for the opportunity of being allowed to congratulate the author upon the Report he had presented. He thought Professor Capper was to be specially congratulated, because he had drawn attention to a point which must be settled before any important gain could be made in steam-engine economy. Since the Paper of Messrs. Callendar and Nicolson, the subject of valve leakage, which they so strongly brought forward, seemed to have been forgotten, and engine builders had gone on imagining that the whole of the missing quantity in any steam-engine was due to initial condensation. The Report now under discussion was a direct confirmation of Messrs. Callendar and Nicolson's work, and ought to draw the attention of engineers to the fact that they should direct themselves to the design of valves which could be used in everyday work, and which could be depended upon not to allow the steam to leak past them. He had been asked by Dr. Nicolson, who was unable to be present, to read some remarks he would like to offer to the meeting, and with the President's permission he would do so. [Dr. Nicolson's remarks will be found on page 330.]

To himself personally the valve-leakage question was one of much interest, because when he was at McGill University as an

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1851 Research Scholar he thought he was the first to make experiments which showed that a slide-valve, absolutely steam-tight when stationary, so soon as it started to move had a very considerable leakage. The experiment was made upon the engine which he thought was described by Mr. Druitt Halpin on the last occasion. The experimental engine at the Manchester School of Technology was specially arranged for leakage experiments. Instead of plugging the ports, they had arranged the valve to work on a loose face, and between the loose face and the cylinder casting a brass plate was fitted. Two brass plates were provided, one with holes, corresponding to the steam and exhaust ports for ordinary working, and the other blank, except for the exhaust port, for leakage experiments. This arrangement enabled one to run leakage experiments with very little trouble, and to be perfectly sure about the joints being tight. They also had a small engine, on which they carried out leakage experiments in the manner described by the author. In this engine they had to block up the ports, and experienced the difficulty which Professor Capper had described in making the joints tight.

If he might offer some criticisms on the Report, he thought it was a pity the author did not take the temperatures not only of the clearance surfaces but also of the valve-faces. If that had been done, some evidence would have been forthcoming to show whether the valve-faces were cooler in the valve-leakage experiments, that is, the port plugged experiments, than they were under ordinary working. In the experiments which he had made himself, with small thermometers in the metal of the steam-ports, he had not been able to detect any lowering of the average temperatures; in fact in some cases the temperatures were higher. Not only that, but on taking by means of a delicate thermometer the temperature of the steam as it leaked through the valve, he had found that in almost all cases it was superheated. When the engine was working, the exhaust steam was not superheated, and it seemed to lower the temperatures of the ports.

It was very remarkable to notice the difference that speed had upon these temperatures. If there were a thermometer in the metal of the clearance surfaces, that is, just at the ends of the cylinder, it

would be noticed that that thermometer remained practically stationary for all speeds of the engine, say from 50 to 300 revolutions per minute; but a thermometer in the metal of the ports which was influenced by the rushing past of the steam would drop considerably with high speeds. It therefore seemed to him that the high speeds lowered the temperatures of the ports, and therefore increased the leakage.

The author mentioned (page 238) that the re-evaporation from the jacketed surface was less than from the unjacketed, and explained it by saying that the regenerative effect was largely independent of the temperature. It was extremely difficult to him to see why that should be so. That was to say, it was difficult to see why, if there were any water present in the cylinder, less should be evaporated from the hot walls than from the cold walls. He thought the true explanation was that, in most cases by the time the piston got to release, there had been complete re-evaporation. In the jacketed engine, he would say that the steam in every case was perfectly dry, and probably superheated before release, and that, even in an unjacketed engine, in a great many cases the steam was also perfectly dry at release. That perhaps might be considered rather a strong statement by those who had carried out engine trials, but it seemed to him to be true. The evidence for it was, first, the Callendar-Nicolson experiments which either had to be accepted or refused. Looking at the condensation areas in their Paper, it would be seen that for admission pressures of about 100 lbs. per square inch they were comparatively small, and that soon after cut-off the re-evaporation area was equal to the condensation area, and therefore any steam that was initially condensed would soon be re-evaporated. In order to obtain further evidence upon this point he made a special experiment, by placing in the exhaust-pipe of the engine an ordinary drain-pipe, into which he put a large number of coils of iron wire. There were two thermometers in the pipe, one on the cylinder side of the wire and one on the condenser side. The arrangement was shown in Fig. 55 (page 292). When the engine was running, those two thermometers gave practically the same reading, but by passing an electric current through the wires, the wires were heated, and

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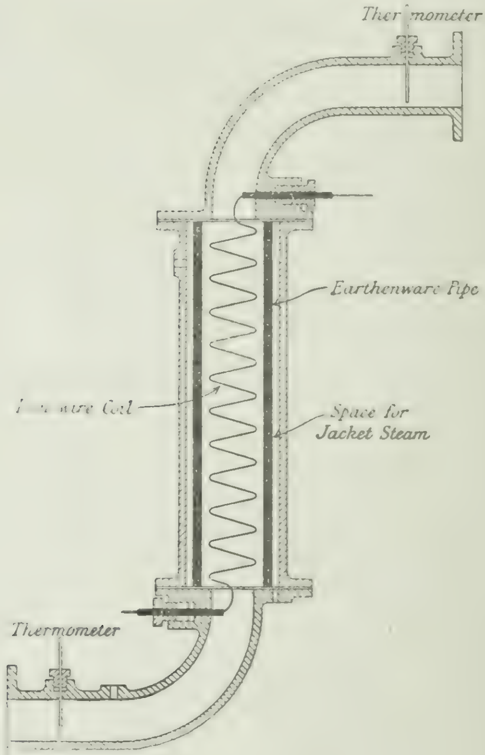
re-evaporated any water that was present. So long as there was any water at all left in the steam the two thermometers read exactly the same, but immediately all the water was re-evaporated the second thermometer commenced to rise. Knowing the ampères and volts

FIG. 55.—*Experimental addition of Heat to Exhaust-Steam.*



used, he could easily calculate the energy put into the steam, and could therefore calculate the amount of water that had been mixed with the steam. In one particular instance he remembered, at release, according to the ordinary methods it appeared as if there were a missing quantity of about 200 lbs. per hour, and it would

have been generally said that there were 200 lbs. of water per hour present at release. The experiment he was mentioning showed that instead of there being 200 lbs. of water at release there were only 12 lbs., an amount that was practically made up by the radiation between the engine and the pipe with the coil in it. He thought that showed at once that if not perfectly dry at release the steam was very nearly dry. If they accepted this view, then it followed that the working leakage was much greater than the valve-leakage experiments showed, and the difficulty of explaining why there should be less apparent re-evaporation for jacketed than unjacketed trials disappeared. It might then be said that there was less apparent re-evaporation, because there was no water in the cylinder left to re-evaporate. He had taken trials No. C_2 jacketed and CC_2 unjacketed, and from them constructed Table 16, correcting the quantities for 100 revolutions.

TABLE 16.

——	C_2 Jacketed.	CC_2 Unjacketed.
Indicated weight at cut-off (lbs. per hour)	287	286
Missing quantity " " (" " ")	73	174
Indicated weight at release (" " ")	325	330
Missing quantity " " (" " ")	35	130
Increase between release and cut-off	38	44

It would be seen that the apparent re-evaporation between release and cut-off was 38 lbs. per hour for the jacketed and 44 lbs. per hour for the unjacketed. The missing quantity of release for the unjacketed was 130 lbs. per hour, and for the jacketed 35 lbs. per hour. He had no doubt whatever in saying that, neglecting the leak into the cylinder, for the jacketed the whole of the 34 was valve leakage, and that the steam was perfectly dry at release. His own opinion also was that for the unjacketed the greater part of the 130 lbs. missing at release was leakage, and that the steam there was also practically dry at release. This showed that one of the

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advantages of the jacket was that it reduced the valve leakage, probably by warming up the valve faces. He thought in that respect it was more useful than in reducing the condensation. The effect upon the condensation, if the engine was jacketed by steam of its own initial pressure, was very little, but the effect upon the valve leakage due to the heating of the ports by conduction was very great. In conclusion, he wished to say that if more engineering colleges were to take up work of the kind described in the Report, instead of devoting themselves solely to the teaching of rudimentary engine-testing, the manufacturers of the country would take a more active interest in the advancement of technical education.

Mr. R. H. Cabena said he wished to draw attention to the point which had been touched upon by almost every speaker, namely, the question of leakage; and in that connection he would refer to the leakage curves. On the last occasion Mr. Longridge pointed out that the curves on Fig. 32 (page 212) were parabolic; in other words the leakage was proportional to the square root of the pressure. He would first ask the author whether the zero point on the curves was obtained experimentally, or whether it was merely assumed that the zero pressure difference was a point on the curves.

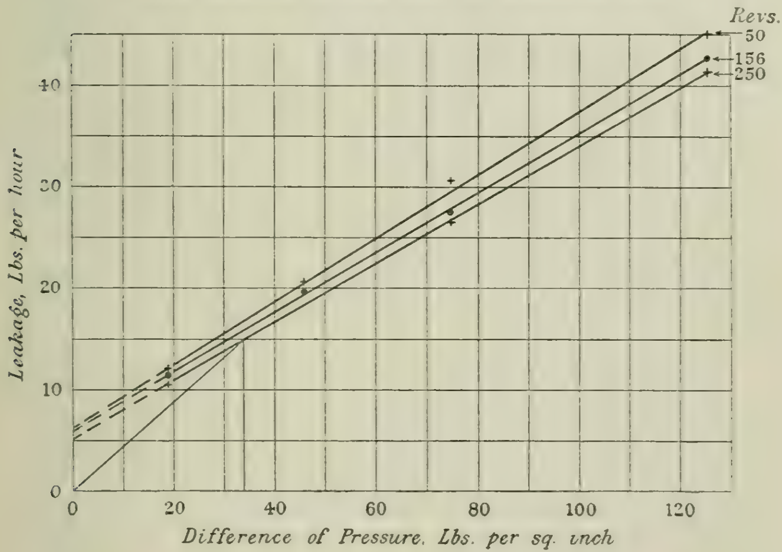
Professor Capper said the point was assumed.

Mr. Cabena, continuing, said that in that case the portion of the curve between zero and the first plotted point was extrapolated, and this was also true of that portion of the curve to the right. There were thus remaining in the curve three experimental points, and it would be found that a straight line would satisfy those three points equally well. With respect to the point marked "lubrication failed," he would say that as the intermediate dotted curve represented the conditions of steam in all jackets, and stopped lubrication, they should expect to find that point on the intermediate curve. Neglecting the last point, on the intermediate curve it would be found that the plotted points also satisfied a straight line. Finally, a straight line would satisfy equally well the points in the upper curve. All of these lines cut the vertical at some point,

indicating an added constant quantity independent of the pressure difference. He suggested that the constant represented mechanical leakage, especially so on account of the experiments being conducted with blocked steam-ports. There was a clearance or pocket formed just over the blocking piece according to the diagrams in Fig. 33 (page 217), and they might reasonably expect the condensation on the cylinder face to be brought along towards the blocked steam-port

Fig. 56.

Slide-Valve Leakage, plotted from Values in Table 2 (compare Fig. 32, page 212). Steam in all jackets. Syphon Lubricator supplying freely.



by the port in the main valve. The exhaust edge of the valve passing over the steam-port would remove that leakage water to the exhaust. These suggestions were of course speculative: there were other ways in which a mechanical leakage could take place. Plotting the leakage and pressure difference from the figures in Tables 1 and 2 (pages 210 and 211)—and not by taking the average values of the last three columns as was done in Fig. 32—he found that they were all straight lines, Fig. 56.

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Taking the lowest line it would be found that it cut the vertical axis at a point representing a mechanical leakage of 5 lbs. per hour. Choosing a point on the axis of pressure difference at 34 lbs. and drawing a perpendicular to meet the plotted line, it would be found that a leakage of 15 lbs. per hour was obtained. He took a point at 34 lbs. pressure, because he found from figures of Dr. Nicolson's that for a difference of 34 lbs. pressure on the valve he obtained a coefficient of 0·02, for a $10\frac{1}{2}$-inch cylinder (which was the nearest size of cylinder for which he had been able to find data).

If they applied these figures for pressure difference and leakage to determine the coefficient C, they would find leakage divided by pressure difference, multiplied by the overlap, upon the perimeter, gave exactly 0·02. That might be a mere coincidence, but it was peculiar that the same pressure gave the same result for these experiments. The total leakage obtained by Dr. Nicolson was greater than that obtained in the present case, but the valve was for a $10\frac{1}{2}$-inch cylinder against that for a $6\frac{1}{2}$-inch cylinder; and therefore the perimeter would be greater. He had not obtained the data for the perimeter of the larger valve, but he estimated that it would be approximately about as much greater as the leakage per hour was greater.

Another point to which he wished to draw attention was in connection with Table 3 (page 214), where in the last two lines the effect of leakage through the valve due to wire-drawing was given. Instead of comparing the second line from the bottom with the lower line, he proposed to take the third line of figures from Tables 1 and 2 (pages 210 and 211 to compare with the lower line of Table 3). Taking those figures, and setting them in Table 3, the following results given in Table 17 were obtained:—

It would be noticed that the leakage 20·6 was not very different from the leakage given in Table 3, 20·4; yet there was 66 lbs. difference in the wire-drawing, and the pressures on the valve were 46 and 45·25. If it were legitimate to take those figures from Table 1 for comparison, then it did not seem to prove that wire-drawing reduced the leakage. There was the remarkable fact about those figures that the pressure upon the valve was practically

TABLE 17.

Revs.	Steam Pipe before Inlet.	Steam Chest.	Exhaust.	Steam Pipe minus Chest.	Steam Chest minus Exhaust.	Leakage. Lbs. per hour.
50	66.25	63	17	3·25	46	20·6
50	132	63	17·75	69	45·25	20·4

the same, and that the leakage was also practically the same. It would be remembered that Dr. Nicolson found that, for a non-balanced valve with 34 lbs. pressure, he obtained a leakage of 41 lbs. per hour; for a balanced valve with 80·5 lbs. pressure he obtained a leakage of 267 lbs. per hour, pointing to the fact that not merely steam-chest pressure minus exhaust, but the actual pressure between the valve and the cylinder face, was a determining factor. He referred to that as being an indication of the reason why the leakage was the same in both cases, namely, that the pressures were equal, and not as a result of wire-drawing.

Mr. Henry Davey, Member of Council, wished to refer in the first place to some remarks which fell from Mr. Maw at the opening of the discussion. He himself had occupied the position of Chairman of the Steam-Jacket Committee since its inception, which he was sorry to say was a long time ago. The Committee set to work immediately it was formed and had done some very useful work. One Report had been read at the meetings, but in the Proceedings of the Institution there were three Reports * which he ventured to say contained more information on the practical value of the steam-jacket than could be found elsewhere in any one publication. It appeared to him that a proposal was now being made to alter the line of research, and to revert to what the Committee started with. The Committee started experimenting with actual

* Proceedings, 1889, page 703; 1892, page 418; and 1894, page 535.

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engines under actual working conditions, testing them with and without jackets, and finding out the differences; and that was the only rational way to get at facts in practical engineering.

He thoroughly joined with other speakers in their appreciation of the value of the present Report. It was valuable not only from a scientific point of view, because it pointed to the direction in which improvements might be effected in the steam-engine, but because it also pointed out defects which many practical engineers perhaps were not quite conversant with. The leakage question, the discussion of which had occupied the whole of the present evening and the previous meeting, was an incidental matter in the Paper, not of the supreme importance of some other facts which had been brought out. He quite agreed with Mr. Maw that it was useless for two Committees to be working on what was practically the same subject. There ought to be an amalgamation; but, when that was brought about and before any future experiments were undertaken, the line of investigation should be thoroughly discussed and laid down with some definiteness. He might mention that Professor Hudson Beare was now carrying out, with an apparatus which he had at his disposal in Edinburgh, some experiments bearing on the value of the steam-jacket; and probably when his report came to be presented it might, to a certain extent, clash with some of the author's investigations.

Having said that much with reference to the two Committees, he would venture to make one or two remarks on the Report itself. The leakage question seemed to be a very vexed one; and he began to wonder when he heard of the enormous amount of leakage which was supposed to take place through valves, how it was that engineers managed to get from steam-engines any efficiency at all. There was leakage of the pistons, leakage of the valves, initial condensation, and all sorts of things; but when one considered that some of the best steam-engines gave 70 per cent. of efficiency on the Rankine formula, one wondered how it was that there was so much leakage, and yet the engines gave such good results. He was convinced that in practical work there was not a leakage from valves that one would be led to expect from the very small experiments carried out. A

theory had been propounded that the valve ran on a film of water, that the water escaped into the port, that the valve would leak water easier than it would leak steam, and that more steam got away in the form of water. On reading the Report and observing that the leakage was somewhat in proportion to the increase in pressure, one wondered why increase in pressure did not squeeze out the film and so make it very much thinner, and if it got thinner the leakage would be very much less. It struck him that the leakage was more with the higher pressure because the valve was not tight to begin with, and never had been tight; it was probably warped. It was natural enough when there was a leakage space, that the leakage should increase with the pressure; it was mere common sense. The investigation which the author had been carrying out had shown how such a leakage might affect the general results. Professor Capper had been quite justified in getting at the leakage first, because his results would be vitiated if he did not know what the leakage was.

With regard to the value of the investigations, he thought they were of a purely scientific value. They were facts that had been ascertained with reference to a particular engine under particular circumstances, and they did not generally apply to engines in actual work; but nevertheless they had their scientific value. There were many anomalies with reference to the economy of steam-engines. It was generally supposed that the faster the engine worked, the better its economy. He thought it was pretty well known that pumping engines, working with a piston speed not exceeding 200 feet and making only 30 revolutions per minute, had given results in economy much higher than anything that had been produced by any other steam-engine. As he had said before, the Paper must be read from a scientific point of view, and hasty conclusions must not be drawn from it and applied in practice.

The gist of the Report appeared to be at the end. In Figs. 44 and 45 (pages 248 and 249) there was some information which was to a certain extent new, and which he thought contained some of the most valuable information in the Report. It appeared from the results that the jacket ceased to be of value when a certain number of revolutions had been attained

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with a certain mean pressure in the cylinder. With regard to the value of the jacket, if the members referred to the three Reports of the Steam-Jacket Committee which had been published in the Proceedings of the Institution, they would find that very elaborate experiments were made with a triple-expansion engine at the East London Water Works, both with and without jackets. Those experiments were carried out with the greatest care and accuracy, and were repeated four or five times with consistent results. The difference between working the engine thoroughly steam-jacketed and working it without any steam-jackets in use was about 3 per cent. As a general fact, the more economical the engine was the less the percentage economy of the jacket. If an engine was using about 13 lbs. of steam per I.H.P. with an initial pressure of about 120 lbs. the value of the jacket became exceedingly small. With an old-fashioned single-cylinder engine, working with only 30 or 40 lbs. of steam, and cutting off at half-stroke, the percentage value of the jacket would be a very different matter altogether.

Mr. ROGER T. SMITH thought that one among the many very interesting facts brought out in the Report was that shown in Fig. 37 (page 229), indicating that as the steam-chest temperature was increased the dryness-fractions all tended to converge to one point. The same thing occurred in Fig. 39 (page 231), and in Fig. 44 (page 248), which had been referred to as one of the most satisfactory and novel results of the Report, exactly the same thing happened. As the initial pressure was increased, that is to say, as the temperature of the steam, in the unjacketed trials, increased, the thermal units per I.H.P. per minute for engines at different speeds, all tended towards one point. The results were all obtained with saturated steam, and through the kindness of Messrs. Belliss and Morcom he had been able to exhibit a diagram showing analogous results from a number of quick revolution engines of different sizes, all of them using superheated steam. On Fig. 57 (page 302) was plotted the variation with superheat of the lbs. of steam per kilowatt-hour supplied to seven engines, each coupled to a dynamo, ranging in output from 220 to 1,500 kw. They were all

non-jacketed condensing engines, and the lbs. of steam per kilowatt-hour had been plotted (from the saturation line as zero) for various degrees of superheat above the temperature corresponding to saturated steam at stop-valve pressure. All the engines were tested at full load, one of them being also tested at three-quarter load ; and all the water measurements were made from the condensed steam. The interesting result was that if all the curves were produced sufficiently far, they met very nearly at one point, namely, 400° of superheat,* showing as a result that if one could only use enough superheat all engines of this type, of whatever size, were about equally economical. From a large number of experiments on the engine marked "A" on Fig. 57 (page 302), a series of curves had been plotted, Fig. 58 (page 303), giving the lbs. of steam per B.H.P. passing through the engine at all loads up to full load for saturated steam, and also for 50°, 100°, 150°, 200°, 250°, 300°, and 350° F. superheat above the temperature of saturated steam. These curves got flatter as the superheat increased, showing that, when sufficient superheat was used, an engine of this type tended to become equally economical at all loads.

He also desired to say a few words with regard to the question of valve leakage. The leakage measurements from the King's College engine had probably come out at as nearly an accurate result as could be obtained. He would like, however, to point out that the effect of leakage, in any given engine, on its economy depended on the size of the ports and the volume of the steam in the cylinder. The area of the port through which steam was admitted should be designed to suit the velocity of that steam. Being anxious to find out how the size of the little engine experimented on would compare with other engines in this respect, he had examined several engines of various sizes and types, and taken out the ratio between the area of the steam port and the volume of the cylinder plus clearance. The ratio had no value in itself whatever ; it only indicated the sort of

* To show this result more clearly, all the engines should be using steam at the same stop-valve pressure. This was not the case, but it has been thought preferable to plot the actual experimental results rather than to rearrange them for one uniform stop-valve pressure.

(Mr. Roger T. Smith.)

FIG. 57.—*Non-Jacketed Quick-Revolution Triple-Expansion Condensing Engines, using Superheated Steam.*

Experiments on Messrs. Belliss and Morcom's Engines.

Set.	Kw. Output of Generator coupled to Engine.	Load at Test.	Stop Valve Steam Press. Lbs. per sq. inch.	Vacuum at Engine. Inches of Mercury.	Date of Test.
A	208	Full	155	26	Jan. 1904.
B	220	,,	175	25	Nov. 1902.
C	308	,,	190	25	Dec. 1902.
D	362	,,	162	25·8	Feb. 1903.
E	500	,,	150	26	Mar. 1904.
F_1	700	,,	190	27	Jan. 1905.
F_2	580	$\frac{3}{4}$	190	27	Feb. 1905.
G	1456	Full	183	26	July & Aug. 1903.

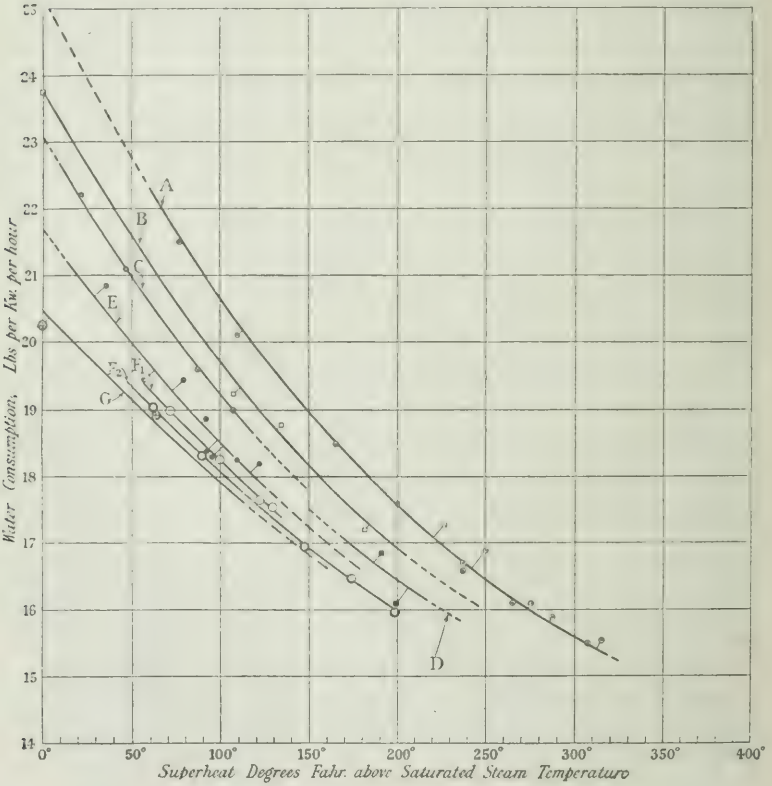
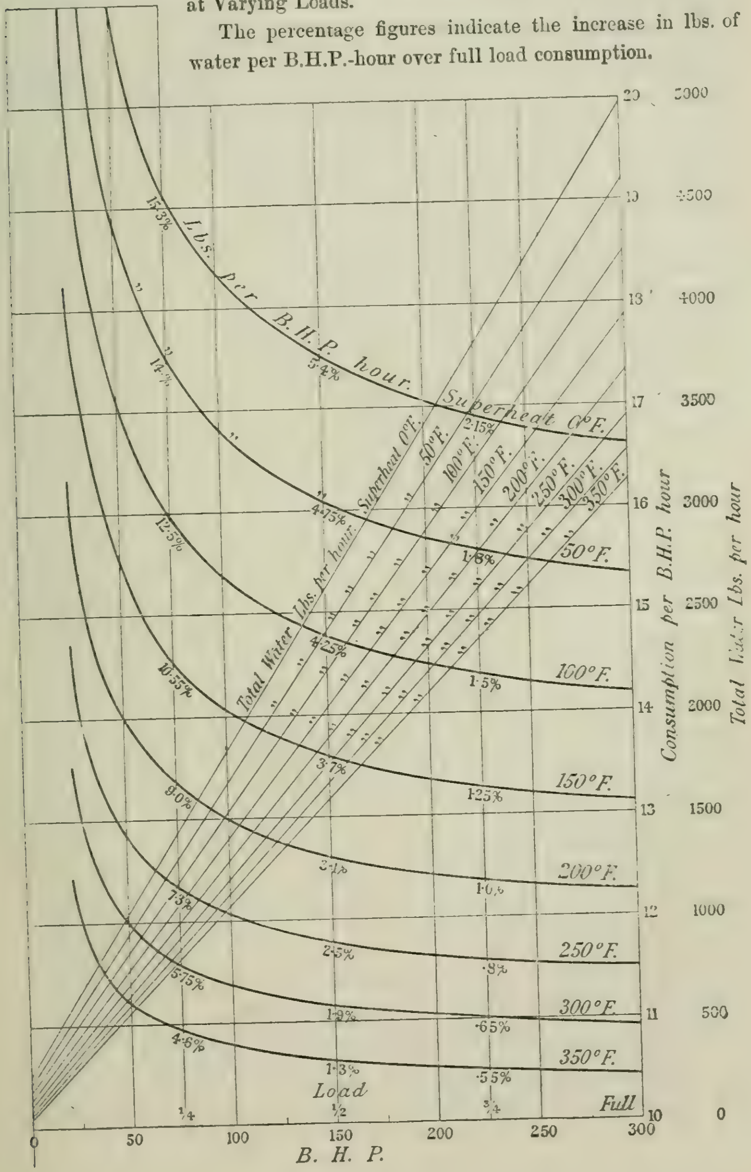


Fig. 58.—*Non-Jacketed Quick-Revolution Triple-Expansion Engine.* (Engine A of Fig. 57), showing effect of Superheat on Steam-Consumption at Varying Loads.

The percentage figures indicate the increase in lbs. of water per B.H.P.-hour over full load consumption.



(Mr. Roger T. Smith.)

relation in size between the space over which leakage could occur and the volume of the cylinder. The results were shown in Table 18 (page 305).

He had not sufficient particulars to work out the leakage perimeter and its ratio to the volume of the cylinder, and had taken the port area as the numerator, since this was applicable to all engines. The Sulzer engine, it should be said, worked a Riedler pump, having the pump valves mechanically shut and opened, and its piston speed was about double what was usual in a pumping engine. He merely mentioned those figures to show that, although the amount of leakage might be as much as 20 per cent. of the steam passing through the cylinder in the small engine used at King's College, when one came to a pumping engine, as Mr. Davey pointed out, the corresponding effect of leakage, owing to the enormous volume of the cylinder compared to the leakage area, was a very different matter altogether, and possibly some of the good results obtained by pumping engines might be due to that. He would also like to mention a couple of results of actual measurements of leakage from a Belliss engine using piston-valves. One of the engines (marked F_1 and F_2 in Fig. 57), a 1,200 H.P. engine, was first tested without any rings in the piston-valve at all, and it did not then give very good steam-consumption results; it was obvious, according to the indicator card, that there was leakage. It was then tested with spring rings in the piston-valve, and there was an increased efficiency in the steam consumption of the engine of 12 per cent. It is right to point out however that this improvement was not all due to reduction of leakage, as the low-pressure valves had been altered, giving a better steam distribution. He would like also to mention another actual leakage test made at Messrs. Belliss and Morcom's works with a small unjacketed high-speed engine, using steam at 80 lbs. worked under various conditions. The piston-valve was fitted with solid rings, which, in the first instance, were actually ground into the valve-chest so that they were as tight as possible. The water-consumption per indicated H.P. was obtained with the engine under those conditions, both non-condensing and condensing, with saturated and with slightly superheated steam, but the actual

TABLE 18.

Table of various sizes of Engines, showing Ratio of Space through which Leakage could occur to Volume of High-Pressure Cylinder and Clearance.

Type of Engine.	I.H.P.	Cylinder Diameter. H.P.	Cylinder Diameter. I.P.	Cylinder Diameter. L.P.	Stroke.	Revs. per min.	Piston speed.	Port Area. ÷ H.P. Cylinder Volume.
		ins.	ins.	ins.	ins.		Ft. per min.	
King's College. .	Up to 40	$6\frac{1}{2}$	—	—	14	50 to 250	116 to 584	$\frac{1}{140}$
"Robb" used in Callendar and Nicolson's experiments. . .	—	$10\frac{1}{2}$	—	—	12	250	500	$\frac{1}{80}$
Direct-acting beam Pumping . . .	75	$16\frac{1}{4}$	—	25	40 and 60	20	133 and 200	$\frac{1}{891}$
Ditto	150	$18\frac{1}{2}$	—	31	44 and 66	20	147 and 220	$\frac{1}{964}$
Direct-acting horizontal pumping with Sulzer valves	650	29·9	—	43·3	41·35	60	412	$\frac{1}{235}$
Belliss and Morcom Quick-Revolution Engine (Size F_1 and F_2 on Fig. 57, p. 302) piston valves	1200	$18\frac{1}{2}$	27	40	20	250	835	$\frac{1}{62}$
J. and H. McLaren Quick-Revolution Engine, slide valves	2500	25	39	$62\frac{3}{8}$	24	200	800	$\frac{1}{197}$

(Mr. Roger T. Smith.)

amount of superheat was not measured. Six thousandths of an inch were then turned off the rings, and the engine was tested again under exactly the same conditions of load and of initial pressure, the result being an increased water consumption per indicated H.P. of $22\frac{1}{2}$ per cent. in the case of the saturated steam experiment, and of $10\frac{1}{2}$ per cent. with the slightly superheated steam experiment, both non-condensing. This showed the immense effect of even slight superheat in diminishing leakage, as referred to in Professor Capper's Table 3 (page 214). With the engine condensing, only one experiment was made with saturated steam, and there the increase of water consumption due to the reduction in the valve ring was $14\frac{1}{2}$ per cent.

Mr. Maw seemed to invite members to say what they thought the Committee should do in the future; and he should like to ask if it would be possible for the Committee to test an engine with drop-valves or Cornish valves. The drop-valve had this very great advantage, especially as far as leakage was concerned, that it could only be used as an admission valve. The exhaust valve must necessarily be at a different part of the cylinder; and it was impossible to have any leakage between the admission and exhaust ports such as occurred with the slide-valve. In that way the drop-valve must simplify results. Also, if the drop-valve was tight cold, one could easily test if it was tight hot; and no leakage, supposing it was tight and remained tight under the heat of the steam, could occur through the valve during the whole of the expansion part of the stroke. Therefore with a drop-valve engine it would appear (if the above reasoning was correct) that a simple experiment could be made by testing the leakage when standing before-hand, and if it existed, the valve could be re-ground so as to eliminate the leakage. He was sure there were a number of pumping-engines round London and other places working hour by hour and day by day under constant loads with drop-valves, some of them single-acting engines, on which leakage experiments could be easily made; and if a large commercial engine of that kind could be experimented with under such conditions, the results would be of advantage to engineers in general.

Discussion on Friday, 14th April 1905.

Mr. MARK ROBINSON, Member of Council, thought that after two evenings of a very interesting discussion the members might approve of shortening the proceedings by agreeing to take as said the compliments which the Report well deserved. He thought the author, after all the praise which had been offered to him, might not less appreciate a little criticism. On page 233 it was stated that "the total condensation up to cut-off increases with increased pressure and temperature of admission. As the cut-off was constant, condensation therefore increases with the difference between the temperature of admission and exhaust." That was the accepted view, well established by Mr. Willans' trials, and many others, namely, that the greater the range of temperature the greater the condensation, though in fact it was but another form of the truism that it took more heat to warm up a given weight of metal to a high temperature than it did to a low one. But on page 236, with the added dignity of italics, it was said that "expressed as a percentage of the steam entering the cylinder, the losses due to condensation on the cylinder walls of unjacketed engines diminish with increased initial pressure and temperature for a given ratio of expansion, quite independently of the influence of speed." The words "for a given ratio of expansion" made the preceding statement true, but he was afraid they also made it largely valueless, and even dangerous, by tending to mislead the learner. The main deduction which *seemed* to be drawn in that paragraph was that the condensation diminished with increasing temperature. Of course it diminished, but it was not *because* of the increasing temperature; it was *in spite* of the increasing temperature. He was aware that the data for this statement would be found in the Paper, and of course the author was under no misapprehension, but he thought the way the facts were presented tended to mislead a reader not well up in the subject. The higher range of temperature, supposing other things to be equal (as the "other things" ought to be, in all experimenting), *increased* the condensation; but since the higher temperature was merely the result

(Mr. Mark Robinson.)
of throttling the steam less, and so passing a much larger quantity through the engine, the condensation, which was more or less a fixed quantity depending on the temperature and not on the quantity of the steam, of course diminished rapidly as a percentage of the quantity of steam used. He could not help thinking that the author might have pointed out, not that the percentage diminished with the rise of temperature, but that it increased with it, although in the present case the increase was neutralised by the merely accidental interference of other causes.

If the work done in a shop was increased, so that the tools were more fully employed, the standing charges would also increase, but in a less proportion than the value of the work turned out; hence they were easier to bear than when the shop was working with only half the tools employed. But he would be a bad accountant who set forth that fact to support a general statement that standing charges diminished when more tools were running, unless he had laid more stress upon the qualification than upon the statement.

With regard to valve leakage, he presumed that question had been fully dealt with by Captain Sankey at the last Meeting, although he had not the pleasure of hearing him; but he could not help inquiring why, in carrying out experiments of a kind in which any serious valve leakage must be fatal to accuracy, such an imperfect instrument as a slide-valve should be used. Heated up on one side with live steam and cooled on the other by exhaust, a slide-valve necessarily warped and twisted, and let the steam through. With Corliss valves and piston-valves to fall back upon, he could not understand why the makers of experimental engines should use slide-valves rather than adopt something better.

Mr. Druitt Halpin was greatly surprised to hear from Mr. Pendred (page 282), in speaking on the question of jackets, that none of the racers that had won first place were jacketed. He had spoken to him about it, and Mr. Pendred had said they were jacketed, but that their jackets were out of use during the time of the tests. If that was so the matter ought to be threshed out, and it ought to be known now before it became a matter so far back in history as to

be untraceable. Taking the engines that ran in 1872 at Cardiff, Clayton's engine certainly was most elaborately jacketed, not alone on the barrel, covers, and valve-chest, but everywhere, the whole thing being put even into the smoke-box. He did not clearly see therefore how it could have been more jacketed. If it was the fact, as Mr. Pendred said, that those jackets were shut off, it would be a valuable thing to know.* In 1887 they ran at Newcastle, and Mr. Pendred said that the jackets were shut off there in the engine which was given the prize. But there were several others that ran, in which he knew the jackets were not shut off. In 1888 they ran in Glasgow, and there he was positive the jackets were not shut off in the winning engine, because he designed the engine himself, and it was so designed that the jackets could not be shut off. The value of jacketing had been discussed a great deal in the Institution, as also had been the increasing their efficiency by ribbing the jackets, and one Professor proved completely to his own satisfaction that the whole thing was nonsense, that it retarded the transmission of heat into the cylinder. But when the amount of heat actually transmitted was absolutely measured by weighing water, and using thermometers, it was found instead of retarding the transmission of heat, the transmission of heat was increased in the ratio of 3·4 to one. He had seen scores of those engines, common, commercial, portable engines, without superheating and without condensing, developing I.H.P. with 19·7 and 19·5 lbs. of water.

With regard to experimental engines, there was one at Nottingham College where the jacketing was carried out from the piston-rod right round back to the piston-rod, including both covers and valve-chests. There was a cover at the end of each cylinder and a false cover outside, so that the whole of the flanges of the covers were also jacketed, and the jackets were ribbed all over and the covers were also ribbed all over. As much heat was got through as possible, and the result was a small engine indicating 30 H.P.

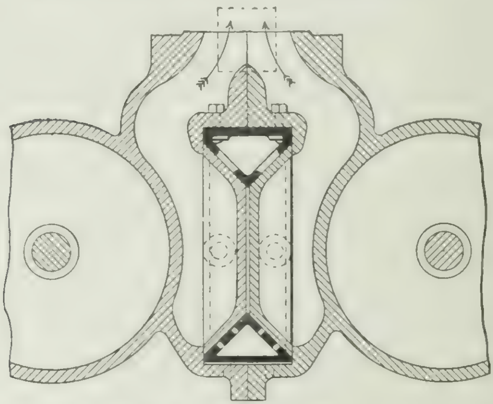
* Mr. Halpin subsequently wrote to Messrs. Clayton and Shuttleworth asking them whether a steam-jacket was actually in use when their engine was tested in Cardiff in 1872, but they answered that all the people connected with the trial were dead, and unfortunately they had no record of the matter.

(Mr. Druitt Halpin.)

with 65 lbs. of steam doing its work on 17·4 lbs. of water without super heating the steam.

The question had been raised of slide-valve leakage. It was in 1870 or 1871 that he first saw a slide-valve working, and the leakage could be seen. He exhibited at the Meeting a model of one that he had at work in a locomotive, 17-inch engine, Fig. 59 (below). The valves were in the open ended steam-chest. The valve-rods went through guides at the back end and the valves leaked. They were scraped absolutely true, but still they leaked. People did

Fig. 59.—*Smart's Balanced Slide-Valve.*
Model exhibited in South Kensington Museum.



not know as much 35 years ago as they knew now, and they could not discover the reason of the leakage. A bucket with heater was used and a fire was put under it, and the water kept boiling, and one of the valves was taken by tongs and put in the bucket, so that it was known that the temperature was at 210° or 212° F. It was taken out quickly, and put on the surface plate again and the whole thing could be seen. Three or four layers of tracing paper were put under the valve at various positions, and the whole valve was found to be buckled up from heat. It might be said that that was an unfair way to look at it, because a grid-iron valve taking steam through it was more complicated than the ordinary flat-valve, and for that reason it might be more sensitive to changes of temperature.

Mr. C. H. WINGFIELD said that reference was made (page 174) to some separators consisting of U tubes, and the result of some experiments which were kindly made by Messrs. Willans and Robinson for him might be of interest. He could not give the exact figures, as they were made for another Committee and he was not at liberty to publish details. Fig. 60 represented the apparatus and showed at A a tube arranged on the same principle as those used by the author. The steam, and whatever water there was at the bottom of the main steam-pipe, entered where the arrow indicated, struck

FIG. 60.
Separation of the Water.

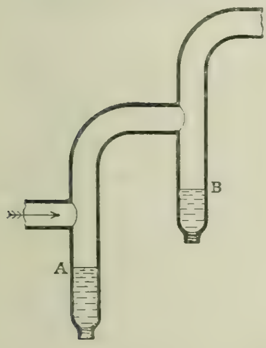
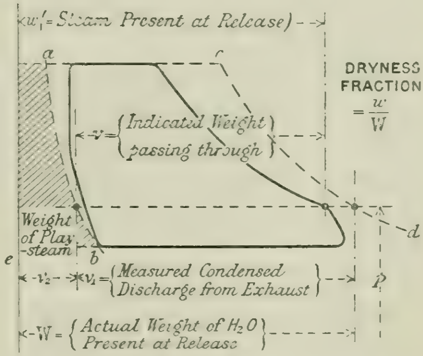


FIG. 61.
Dryness-Fraction.



against the side of the vertical pipe, and the steam went upwards, the water being supposed to drop down to the bottom. He had great doubts as to the efficiency of such a device and, in order to ascertain if these were well founded, a second separator B was fitted in series with A. If the separator marked A was perfectly efficient, there would be no water in B except such as was condensed between the two. This could only be minute in quantity, as the whole apparatus was very carefully lagged. The result of the experiments was that, when steam was passing slowly, rather more water was caught in A than in B, and when it was made to pass quickly more water was caught in B than in A.

He wished to say a few words about the " dryness-fraction " as,

(Mr. C. H. Wingfield.)
although of great importance in the thermodynamics of steam, its meaning was sometimes misunderstood, and the author was not quite so clear in his words as he knew him to be in his mind on this point. In an indicator diagram, such as shown in Fig. 61 (page 311), horizontal distances corresponded, as was well-known, to volumes, when measured on a suitable scale. Let two saturation curves *a b* and *c d* be drawn; the former through *b* (the point where the exhaust-valve closed) and the latter at such a distance from *a b* that, if any horizontal line were drawn through the two curves, the length of the intercept between them would represent the volume which the weight of steam and moisture discharged through the exhaust pipe at each stroke would occupy (if it were all in the form of saturated steam), at the pressure corresponding to the height of the horizontal line in question.

Similarly, the horizontal width of the shaded area at any point was a measure of the volume of saturated steam (at the pressure corresponding to the height of the selected point), which was equal in weight to that of the volume *c b* of "play-steam" * shut up in the cylinder and clearance when the exhaust-valve closed at *b*. Although not measured with the condensed discharge from the exhaust, this "play-steam" was present in the cylinder and clearance throughout the expansion, and its weight must therefore appear both in the numerator and denominator of the "dryness-fraction." At any one pressure, such for instance as the pressure *p* of release, horizontal distances might equally well be taken as measures of weight as of volume, and the figure was marked accordingly. In the terms shown on the diagram, the dryness-fraction at "release" was obtained by dividing *w* by W, and this agreed with the author's definition on page 239, which he would take the liberty of somewhat amplifying, namely, the "ratio of steam present in the cylinder at cut-off" (or any other point in the expansion-curve) "to the total steam and moisture" then present in the cylinder. (Of course in the term "cylinder" the clearance volume was included.)

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* A name introduced by Mr. Macfarlane Gray.

Another definition was, however, given on page 226 (in which the "play-steam" did not appear in the denominator) corresponding to w/v_1 in Fig. 61 (page 311), and he suggested this should be corrected in the two places where the slip occurred. [This has been done.]

Yet another definition had been given in a popular text-book,* which was quite incorrect. It would correspond with v/v_1 in Fig. 61, if the compression line followed the saturation curve as the author of the book appeared to have assumed. This was by no means necessarily the case, however. The fact that the speaker had often found confusion to exist with regard to the "dryness-fraction" must be his excuse for dwelling upon it at such length.

On page 225 it was mentioned that in some of the indicator diagrams the admission line sloped considerably. As far as he could see, the author had taken the highest point as the admission pressure. Mr. Willans, in the first of his classical papers, took the *mean* admission pressure, because he considered that the results obtained in calculation on that basis were more consistent than when he took the top of the line. In his second Paper, however, he abandoned the first practice in favour of the second.

On page 175 he noticed that the vacuum was regulated by opening an air-cock to the condenser. As a matter of interest he should like to know whether this cock wanted much attention, in order to keep the vacuum constant. A rather interesting action took place when air was mixed with steam. It might be known, but he did not think it was as well known as it should be. When even a very small quantity of air went into a condenser it was astonishing, at first sight, to find how much the vacuum was affected. What happened, he believed, was that the air and steam mixed up with more or less uniformity, probably less. Particles of steam charged with air came into contact with the cooling surface, and were condensed, each leaving its partner of air behind it. Gradually, enough air was accumulated to make a cushion of approximately non-conducting material, which reduced the efficiency of the condensing surfaces,

* H. A. Golding's "Theta-phi diagram" (1898 edition), page 22.

(Mr. C. H. Wingfield.)
until a puff of steam came and blew it off, and then the action began again. On this account he anticipated the air-cock might want a good deal of regulation to maintain a uniform vacuum.

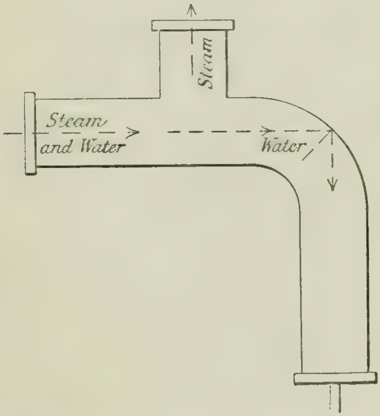
On page 190 the author referred to a standard of comparison, in which he took the same upper limit of temperature as that which was fixed by a committee of the Institution of Civil Engineers, namely, the temperature at the stop-valve. When dealing with the actual engine however, the preceding paragraph showed he took the temperature of the steam-chest as his upper limit: this being less was rather in favour of the engine. The lower limit for the standard engine was not given, but in the case of the actual engine the author took the temperature of the condensed water issuing from the condenser. The Institution of Civil Engineers fixed it as the temperature of the steam issuing from the exhaust branch of the engine. No doubt the author had good reasons for departing from their standard in these respects, and it would be interesting to know what they were.

In conclusion, he did not think sufficient attention had been called to diagrams, Figs. 44 and 45 (pages 248 and 249). They were most valuable because, while they showed (what everyone, more or less, thought they knew) that at high pressures jackets began to lose efficiency; they also showed there was a lower limit, and that the jacket was only useful between those limits. The author had done some very good work in that, and it ought to be appreciated.

Mr. Michael Longridge, Member of Council, desired to say one or two words about steam separators, because evidently from the diagrams and from many designs of separators which he had seen, there was a considerable misapprehension about the way they worked. Most of the separators designed proceeded on the principle that there was a quiet atmosphere within them, whereas as a matter of fact there was a gale of wind blowing through them, and a very heavy gale too. If one tried to heat the water out of the steam by directing the stream against a surface, the water was broken up into a spray of small drops which were easily blown away by the gale of wind and carried forward in the steam; but if one took advantage of the

momentum of these drops and allowed them to continue their course and deflected the steam, most of the water would be separated from the steam. Probably most of the members had played the game of billiards, and they all knew that if a ball was directed against the cushion it would rebound obliquely, the paths before and after contact making approximately equal angles with the normal to the cushion at the point of contact. In the same way a particle of water coming along the pipe, as sketched, Fig. 62, would strike the surface of the pipe and would come off at an equal angle to the normal to that

FIG. 62.—*Steam Separators.*



surface and go down the pipe, whereas the steam would find its way straight up. That he thought was the proper principle on which to make a separator.

Mr. H. E. WIMPERIS said that the idea was to have as few variables as possible (page 173), and that the two should be temperature and speed, the cut-off and all other conditions being kept constant. That seemed to him a most excellent thing. The Paper was a sort of quarry in which other people might work. Mr. Willans had given a somewhat similar Paper many years ago, and many people had been at work on it, prominent amongst them being Professor Perry ; since then a Paper on Gas-Engine Experiments had been read by Professor Burstall and now there was this Paper by Professor Capper. All

(Mr. H. E. Wimperis.)
those Papers were most useful in furnishing material to investigators, especially to those of the student class, as it familiarised them with the ideas that underlay steam-engine and gas-engine working. There was a very important statement on page 177, and one to which but little attention had been paid. It was said : "If on working out any trial any of the conditions or observations were found to vary beyond definite limits, the trial was rejected and repeated." Doubtless Professor Capper in replying would mention what those limits were. It was absolutely necessary in certain cases to work on a rule of that kind, but it was easy to see that great danger was incurred unless it was worked on the most conservative lines.

On page 179 were given the errors due to backlash in the indicator, and he confessed he did not understand the explanation given at the bottom of the page. If the backlash was constant on the up-stroke and on the down-stroke, seeing that the indicator pencil must move up as much as it moved down and move to the right as much as to the left, one would imagine that the area of error would have been the same for all size of diagrams, and although more important for small ones would not be affected by the considerations stated in the footnote. On page 222 the piston leak was found to be less than 2 per cent. of the steam consumption of the engine. How did that agree with a calculation based on the customary formula? If he might do so without presumption, he would like to congratulate Professor Waynforth on being so happily associated in so important a work and in the privilege of working under so distinguished a chief.

Professor Capper, in reply, said he would not detain the meeting long, but would begin by thanking those who had spoken so kindly about the work embodied in the Report. It had been an arduous work, but it had been a work which had been intensely interesting. One of the great difficulties had been the mass of information accumulated, and it had been extremely difficult to compress it within the limits of a single Paper. For that reason there was no doubt that some of the criticism that had been called forth had only too great justification. Dealing with points raised in discussion he

might perhaps deal with those which had been made that evening first and reply to them in the reverse order of the speakers.

Mr. Wimperis (page 316) asked how far the piston leak found by experiment agreed with formula? He was not quite clear to what formula Mr. Wimperis was referring; he thought it was probably the formula by Callendar and Nicolson for slide-valve leakage. But that formula did not really apply in the case of the piston leak. He did not moreover think the formula was a final one, as he would show later on. Mr. Longridge had given a very lucid and interesting description of how to make separators, which was extremely helpful, as Mr. Longridge's suggestions generally were. Mr. Mark Robinson had attacked one passage in the Report, and added that no doubt it would be intelligible if the Paper were carefully studied. To pick out a clause as Mr. Mark Robinson did and to say that that clause might be misunderstood, if the text was not read, was perhaps a little bit unfair to one who was trying to make lucid what was a very complicated subject. He really could not write a Paper on such a subject that would be clear to those who did not take the trouble to read it.

With regard to the dryness-fraction, Mr. Wingfield criticised the definitions in the Paper as ambiguous, but, as far as he could gather, Mr. Wingfield's definition was exactly the same as his own. If the members would turn to page 226, they would see that what he said was not in the least that the dryness-fraction was the ratio between the steam consumed by the engine as measured on an indicator and the condenser discharge, but the ratio between the steam measured upon the indicator card up to cut-off or release and the measured condenser discharge from the exhaust. That was exactly the ratio $\frac{w}{W}$.

Mr. Wingfield said he was speaking of the denominator W.

Professor Capper said that w was the whole steam up to the saturation curve and therefore gave the same ratio as Mr. Wingfield. He would alter the wording before the final reprint so as to avoid any possible ambiguity.

(Professor Capper.)

With regard to trial B_1 (page 198), if the Paper was read, a full explanation of the irregularity in the dryness-fractions of B_1 would be found. This trial was dealt with at considerable length. The steam at admission on this trial was dryer than on the others, because in B_1 there was a considerable additional throttling, and therefore the steam when admitted was dryer than in the other cases. That was the reason why B_1 showed irregularity with regard to dryness.

Mr. Pendred drew attention to the fact that an experimenter was very apt, however strenuously he might endeavour to avoid the fault, to be led away in a scientific laboratory experiment from the usual conditions of working practice. In order to make experiments of the sort described, as anyone who had tried would know, one must of necessity prevent a large part of the accidental discrepancies that occurred in ordinary practical working, or else one could not get the information one was seeking at all. Therefore when it was urged that during the experiments ordinary working conditions did not obtain, one could only say humbly that some of the variables must be cut out or else scientific information could not be got at all. When Mr. Pendred said that the author did not make himself quite clear with regard to the question of re-evaporation he thought it would be possible—although he should be sorry to do so—to retort that Mr. Pendred still more laid himself open to attack when he said (page 283) that "whatever went into the cylinder as steam must leave it as steam, and whatever went into it as water must leave it as water," and made that bold statement without any limitation whatever. That statement was perfectly untrue, if it was not very carefully qualified. It was only true with a closed cycle. In the experiments under discussion the author was not concerned with what happened after opening to exhaust. After opening to exhaust, such very variable conditions existed that any exact determination of what was taking place was extremely difficult, and even if this were determined, except as regards the main factors, such as temperature pressure, etc., the results were not of much practical value to the particular enquiry under discussion. The work in the present experiments had chiefly been devoted to trying to determine the

laws governing initial condensation. This was the original object of the enquiry. Therefore, when in the Report he spoke of "re-evaporation," he spoke of re-evaporation in its usual acceptation, that is, up to the point of release. After that point there was of course a great deal of re-evaporation into the condenser, but they were not concerned with that phenomenon.

With regard to jackets, Mr. Pendred had said (page 282) that many experiments had been made thirty-two or thirty-three years ago on jackets, and it was found in all cases that the engines without jackets were more economical than those with. He did not wonder at that. Countless experiments could be adduced to show that and countless others to show the contrary. Very little was known about the behaviour of the jackets thirty-three years ago. It all depended on whether the jackets were used and worked soundly or not, and he hoped he had possibly added a little to that information by this Paper. If one used jackets (as was generally the case thirty-three years ago, and was sometimes the case even now) without providing any possibility for the steam to circulate in the jackets, one might just as well put the cylinder into the condenser at once; and consequently one was likely under those conditions to find the non-jacketed engine more efficient than the jacketed. If enquiry was made into many of those cases where the jackets were detrimental, it would be found that instead of being steam-jackets the jackets were really water-jackets, and for that reason a good many of the comparative experiments were worthless.

The main portion of all the remarks that had been made had been devoted to valve leakage, as might have been expected. It was an extremely important subject, and an enormous debt of gratitude was owing to Messrs. Callendar and Nicolson for having first drawn attention to it. But an enormous grudge was also owing to them from the experimenters who came after them, because they had enormously increased the labours of anybody who followed after them. It was perfectly impossible to get any reliable results as to initial condensation and re-evaporation, without measuring the valve leakage. Therefore it was desirable to so add up and pile up experiment on experiment on different types of valve, on different ways

(Professor Capper.)

of working valves, and so on, that knowledge might be gained of what leakage was likely to be obtained under any given set of conditions. He hoped nobody would think that he pretended these experiments were in any way exhaustive. They had, as Mr. Maw said, only just touched the fringe of the subject, and he hoped that others working on the same lines would add vastly more information. The law of leakage suggested by Messrs. Callendar and Nicolson, which he had accepted tentatively, and only tentatively, was thrown out as a working hypothesis. It seemed to him that the best way to try and add to knowledge was to take the hypothesis of one's predecessors and see how far one's own results concurred with this hypothesis. Therefore, as he stated in the report, he had adopted the constant suggested by Messrs. Callendar and Nicolson. The present experiments showed that the value of C, which on their hypothesis should be a constant, varied so much that it was not a constant at all. That showed that the assumptions made must be modified, and that the suggestion of Messrs. Callendar and Nicolson was only a tentative one. Mr. Longridge and other speakers had rightly pointed out that there were certain indications—he would not say more because the experiments were not numerous enough to be sure about it—but there were indications that the variation of leakage was possibly not directly as the pressure but as the square root of the pressure. Mr. Cabena at the last Meeting rightly pointed out that the results on Fig. 32 (page 212) really lay on a straight line and that the first part was extrapolated. If that straight line were produced back to the origin of pressure differences, it would be found that at zero pressure there was still a leakage which Mr. Cabena attributed to mechanical leakage. That was perfectly true, and he himself was struck with it when he first plotted the curve. He drew out the curve in all sorts of ways varying with temperature, with pressure, and with difference of pressure.

Professor Burstall pointed out (page 286) that the curves were straight lines which came to an origin of temperature, but it was curious that if the points were drawn as straight lines they also came to an origin of pressure, not of difference of pressure but of

absolute pressure. Starting from zero of pressure instead of a zero of the difference of pressure, a perfectly straight line was obtained from those points. He failed to see any physical explanation of this fact, but it was suggestive, possibly as Mr. Cabena said, of mechanical leakage taking place.

Mr. Cabena had also remarked on the lubrication failure. That was rather an interesting point, and perhaps in his desire in the Report to be succinct he had not been absolutely clear. Not only did lubrication fail in that case, but as a matter of fact the valve seized and was scored. The valve was taken out and he made some subsequent experiments to see what the effect of the scoring was, and the interesting point was that after the burr had been taken off—there was one pretty deep score in the valve—the leakage seemed to be reduced by that score. That no doubt, Mr. Longridge would say, was just as he expected. The effect of having a score which came quite close to the edge of the valve was, as far as it had any effect at all, to reduce the leakage, partly probably owing to the fact that there was improved lubrication and possibly owing to what Mr. Longridge maintained, that a valve which had no lap at all except a line would be really more tight than one which had lap. As he had shown in the Paper this view was not borne out by experiment.

Mr. Stromeyer had referred to Fig. 36 (page 222) and asked why the experiments were carried out under such bad conditions; and in his usual thorough manner, after working out the weight of the steam at each point of the stroke from the diagram, said that there must have been some communication with the atmosphere. As a matter of fact there was, because the leak was being measured at the time, and naturally there was a communication through a suitable trap with the atmosphere, and that was of course what upset the diagram from Mr. Stromeyer's point of view. He thought Mr. Stromeyer took it as though the blocked end was simply shut up, in which case of course there would not have been the variation he alluded to. Mr. Stromeyer's figures bore out the view that the leakage was negligible from the piston under all conditions.

He had to thank Mr. Maw especially for his kind remarks (page 267). Mr. Maw asked him to explain how the lubrication of the

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valve was carried out (page 270). It was carried out in the following manner. There was a sight-feed lubricator which entered the steam-pipe after the stop-valve. There was an ordinary siphon lubricator on the top of the steam-chest, and the sight-feed lubricator was run in all cases as stated in the Tables at about two drops per minute. The difference between the two top curves of Fig. 32 (page 212) and the bottom ones was that in the bottom ones the siphon lubricator on the steam-chest was running freely, while in others the siphon lubricator on the steam-chest was stopped. Where there was not a large quantity of steam passing through, as, for instance, when the only steam passing was the steam that had leaked past the valve, one would expect to get a more perfect lubrication than would be obtained with the full quantity of steam running through, as would be the case when an engine was in full work. Mr. Maw had also asked at what pressure the jackets were supplied with steam. In all cases the jackets were supplied with steam at steam-chest pressure.

Professor Burstall had pointed out (page 286) that the leakage of the slide-valve was probably to a large extent due to the warping of the valve. That was possibly right. He also pointed out as already noted that the leakage varied as the temperature, if the diagrams were drawn on a scale of temperatures. He was also surprised at the dryness of the steam. That again was due to the difficulty of thoroughly reading the Report in the short time at the disposal of the members. It was fully explained in the Report that the steam was dry partly owing to the fact that a separator was used somewhat of the form, but not quite the form, of that suggested by Mr. Longridge, and secondly because it was found impossible to get steady and uniform pressures in the steam-chest from the boiler without throttling. As a result, the steam was in all cases dried to a certain extent before coming into the cylinder by that throttling.

Mr. Mellanby had made some very interesting and instructive additions to the discussion both on his own behalf and that of Dr. Nicolson, whose opinion on the question was of course of great value. He said they were making experiments in the laboratory at Manchester with a loose slide-face and a plate underneath, and from these experiments they found the leakage in actual running was twice as much as the

experimental leakages with blocked ports. He knew Dr. Nicolson's skill and care in experimenting would not allow him to do so, but it was possible one might not get a perfectly tight joint with a face of that sort, and it was possible that there might be an addition to the leakage in that way. He could not believe that there was generally leakage to the extent suggested in ordinary practice.

Mr. Pendred had remarked that these experiments had been made on one engine, and generalisations made from it for all engines (page 284). He did think that he really had protected himself against criticism of that sort. He must repeat again that he did not say that the results he had got from the one engine were universally applicable. But individual experiments after all were of value, and if those individual experiments were multiplied on a number of engines then real progress in knowledge would be made. To that end he claimed that this research was a real contribution. The lines on which the Committee might very usefully make further investigations would be partly on the lines which Mr. Maw suggested, namely, making experiments on a number of different valves, if one could get large engines placed at one's disposal. Also there was a very large amount of information he should like to be able to obtain on the increased range of temperatures due to running the engine condensing, and also on the effect of changes in the ratio of expansion. The whole of the results were limited by the fact that there was a constant ratio of expansion throughout.

Captain Sankey's results (page 277) on the Willans engines were extremely important, and Mr. Roger Smith's contribution on the effect of superheating was also of great value and very instructive. Captain Sankey had also kindly pointed out the slip of the tongue by which he had attributed the name temperature-entropy to Mr. Macfarlane Gray instead of $\theta\phi$ which he intended to say. He thanked all who had spoken for the kind way in which they had received his researches, and he hoped no one would consider that the results were final but only suggestive, and that they were suggestive for good and not for evil. He trusted that the Report would prove a means by which future workers might find help in elucidating the problems better than he had been able to explain them.

On the motion of the PRESIDENT, a hearty vote of thanks was accorded to Professor Capper.

Communications.

Mr. E. A. FORWARD wrote that with regard to the valve-leakage diagram, Fig. 32 (page 212), the author had stated that the last point on the lowest curve was too high owing to the failure of the lubrication, and that the valve actually seized. The curves were, however, plotted from the mean of the figures given in the last three columns of Table 2 (43 lbs.), and the writer would like to know whether the lubricant failed in all three experiments, as the lowest figure 41·2 lbs. was also very much above the full line curve. His own opinion was that valve leakage was by no means so serious as these experiments appeared to show, and he believed that the method of testing with blocked ports was not sufficiently representative of the actual working conditions of the engine. It seemed to him that while the steam was flowing into one or other of the ports very little would leak under the valve, and it was only when this flow ceased that the conditions became in any way similar to the experimental ones. He would suggest that leakage experiments should be carried out on a cylinder provided with an ordinary three-ported valve-face and also extra exhaust-valves. The ordinary valve should be replaced by a flat plate, and the engine worked under steam as usual. Something like the true leak would then take place from the steam-chest to the dummy exhaust.

Mr. A. T. J. KERSEY wrote that the discussion had hitherto been almost wholly confined to valve leakage. This was, of course, a most important question, since the accuracy of other conclusions depended upon the correct deductions being made for leakage, but it must be regarded as merely incidental to the main object of the research, that is, to determine how initial condensation and

re-evaporation were affected by the range of temperature in the cylinder and the speed of the engine. The deductions made for valve leakage appeared to be sufficiently approximate to enable conclusions to be drawn as to condensation in the cylinder, but further extensive experiments appeared to be necessary in order to determine how much of the leakage was due to condensation and re-evaporation and how much to distortion of the valve due to the high temperature of the steam.

With regard to the effect of range of temperature on condensation, it appeared to be quite hopeless to expect to obtain any simple law connecting these. In the first place, the temperature of the steam diminished continuously from cut-off to release. There was then a drop of temperature, and the return stroke took place with exhaust steam of a constant temperature until compression took place, raising the temperature before admission. In this connection it might be pointed out that the effect of compression was of greater importance in the A trials than in the D trials. Thus far more heat would be lost by the clearance spaces during exhaust than during expansion, so that, apart from the effect of time on the variation of temperature of the clearance surfaces, it would be seen that the initial condensation could not be expressed as a simple function of the total range of temperature of the steam. It seemed to him that, if the results were to be of comparative value and any quantitative laws were to be deduced from the research when completed, some mathematical theory based upon the thickness and conductivity of the metal and the cyclical variation of temperature expressed as a Fourier series was desirable before a series of experiments of this kind was attempted, in order that there should be no complication due to more than one variable in any one set of experiments. Such a theory would be highly complicated by the fact that all parts of the cylinder walls were not subjected to the same range of temperature, but in the absence of a theory extreme care was necessary in settling the variables, it being evident that mere range of temperature was not a simple variable. Now in this series of trials the range of temperature was changed by altering the initial pressure, and this complicated matters, since, as stated in the

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Report, the initial condensation was affected by alteration of initial pressure, owing to the exposed surface per lb. of steam admitted being thus altered; and more satisfactory conclusions might have been drawn if it had been possible to keep the initial pressure constant and vary the back pressure in order to vary the temperature range. This could be accomplished by means of a loaded valve on the exhaust, and he did not see any special difficulties which could not be overcome. He would like to make it clear that these criticisms were not offered in any carping spirit. The general conclusions drawn from the Report were most valuable, but there was a difficulty in analysing the results owing to the complication of variables.

Since the back pressure was constant in all the experiments, the writer had endeavoured to deduce laws connecting condensation with speed and initial pressure. In the absence of a theory such laws were, of course, not necessarily of general application, and he had not then access to other experimental results in order to check them. They might, however, be worth a certain amount of consideration. The following was a summary of the conclusions arrived at for the unjacketed trials, and it would be found that they agreed fairly well with the experimental results.

(1) Wetness-fraction at cut-off (deducting leakage) $= \dfrac{6 \cdot 37}{\sqrt[3]{p.n}} = y_0$.

From this the initial condensation per stroke might be deduced as follows:—

Volume of indicated steam per stroke $= c + x$

where $c =$ clearance volume

$x =$ volume traced by piston at cut-off.

Let $w =$ weight of 1 cubic foot of steam,

Then, total weight of steam per stroke $= \dfrac{w\,(c + x)}{1 - y_0}$,

Therefore weight of condensed steam per stroke

$$S_c = w\,(c + x)\left\{\frac{1}{1 - y_0} - 1\right\}$$

$$= \frac{w . y_0 . (c + x)}{1 - y_0}$$

Taking the value of y_0 given in (1), then

$$S_c = \frac{6 \cdot 37\, w\,(c + x)}{\sqrt[3]{p.n} - 6 \cdot 37}$$

From data given $c = 0 \cdot 029$ cubic feet; $x = 0 \cdot 093$ cubic feet. For the range of pressures given

$$w = 0 \cdot 0022\, p + 0 \cdot 009.$$

$$\text{Therefore } S_c = \frac{0 \cdot 00178\, p + 0 \cdot 00717}{\sqrt[3]{p.n} - 6 \cdot 37}$$

Owing to wire-drawing, compression, etc., a coefficient of $0 \cdot 85$ has to be applied, and the following expressed the actual weight of condensed steam per stroke

$$(2) \qquad S_c = \frac{0 \cdot 0015\,(p + 4)}{\sqrt[3]{p.n} - 6 \cdot 4}$$

The ratio of re-evaporation to condensation is fairly well expressed by

$$(3) \qquad \frac{S_e}{S_c} = 0 \cdot 07 \sqrt[3]{n}$$

Therefore net condensation per stroke

$$(4) \qquad = \frac{0 \cdot 0015\,(1 - 0 \cdot 07 \sqrt[3]{n})\,(p + 4)}{\sqrt[3]{p.n} - 6 \cdot 4}$$

This expression was less complicated than the probable correct expression taking all the conditions into account.

Other approximate laws were

$$(5) \text{ Missing steam per I.H.P. hour} = \frac{9500}{p\sqrt{n}}$$

$$(6) \text{ Indicated steam per I.H.P. hour} = 18 + \frac{420}{p - 16}$$

$$(7) \text{ Therefore } \frac{\text{Missing steam}}{\text{Indicated steam}} = \frac{528}{p\sqrt{n}} \times \frac{p - 16}{p + 7 \cdot 3}$$

He had much diffidence in presenting these conclusions, but it seemed impossible to express them as simple functions of the temperature range.

It was a great pity that so many isolated sets of experiments were being carried out by other observers, without any co-ordination of purpose or even knowledge of each other's work. It would be of

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immense value if a series of tests exactly similar to these could be carried out simultaneously on say half-a-dozen engines of different types, so that the idiosyncrasies of a particular engine might be eliminated, or at least discovered, from the general conclusions drawn.* He was in thorough agreement with the remarks of Mr. Mellanby (page 294) as to the desirability of furnishing engines in technical institutions which provided something more than instruction in ordinary commercial testing routine. He suggested that a committee of the Institution could do much in the way of advice and criticism, if experimenters could be induced to put their schemes before this committee with a view to a scientific sequence of experiments on determined lines.

Mr. William Mason wrote that during the discussion on Messrs. Callendar and Nicolson's Paper on "The Law of Condensation of Steam,"† Mr. Druitt Halpin mentioned that he had tested a slide-valve of the balanced type for warping. The face of the valve when cold was trued to a surface plate; but there was serious warping shown when the valve was made hot in boiling water and again tested on the surface plate. The valve of the experimental engine when similarly tested had no warping which could be detected by ordinary methods of measurement.

It was interesting to estimate the mean thickness of the film of water leaking past the valve. This film would vary in thickness all round the valve, and also as the valve moved. But assuming, for the purpose of estimation, that it was uniform, and 0·0004-inch thick round a perimeter of 22·5 inches, the velocity of the water (if water only and no steam transpired) worked out at from 1 to 4 feet

* To take one instance, let them consider another engine with the same cylinder-volume, but different diameter and stroke. For the same cut-off the same weight of steam would be admitted, but the exposed surface would be much different, and this would affect the initial condensation. For example, a cylinder 8 inches diameter and 12 inches stroke would have 30 per cent. more exposed surface per unit volume than a cylinder 10 inches diameter and 7¾ inches stroke, taking cut-off at 0·25 in each.

† Proceedings, The Institution of Civil Engineers, 1897–8, vol. cxxxi, page 212.

per second for the leakages measured. The figure 0·0004 inch was chosen because this was the minimum thickness of oil film calculated by Professor Osborne Reynolds for one of Mr. Beauchamp Tower's experiments on Journal Lubrication; a value the order of which was afterwards checked by direct measurement.

Professor Burstall has pointed out (page 286) that if the diagram, Fig. 32 (page 212), of the Report, be plotted with differences of temperature as abscissae instead of with differences of pressure, then the leakage curves became straight lines. If this was done for the full-line curve, which represented the most reliable and consistent series of the trials, the straight line passed almost exactly through the origin. The point was worth further investigation; for on temperature or temperature difference depended (1) warping of the valve, (2) condensation on valve surface, (3) the viscosity of water.

Professor Capper had not recorded in the Report what the condition of cylinder lubrication was during the trials. It was well understood that an abundance of lubricant in the cylinder diminished condensation a great deal. Messrs. Callendar and Nicolson mentioned that examination of the cylinder after sundry of their trials always showed very little trace of oil. Professor Nicolson has expressed the opinion that leakage under working conditions will be more than that measured with blocked-up steam ports. This was remarkable, because in the Paper above referred to, the values of the condensation calculated by the method of "condensation areas" agreed closely with those found from the feed and indicator diagrams, after allowing for leakage measured with blocked ports. The greatest divergence between the two sets only corresponded to 3 per cent. difference in the measured leakage, so that this close agreement was apparently a check both on the "method of condensation areas" and upon the assumption that the working leakage agreed with that measured.

Mr. Edmund L. Morris, referring to his remarks on the Paper by Mr. Barr on "American Pumping Engines," * wrote that some

* Proceedings 1905, Part I., page 40.

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further experiments had been made on No. 7 Engine at Hornsey, which might be of interest:—

(1) Without steam in the cylinder-jackets or reheaters.

(2) With steam in the cylinder-jackets, but not in the reheaters.

(3) With steam in the cylinder-jackets, and also in the reheaters.

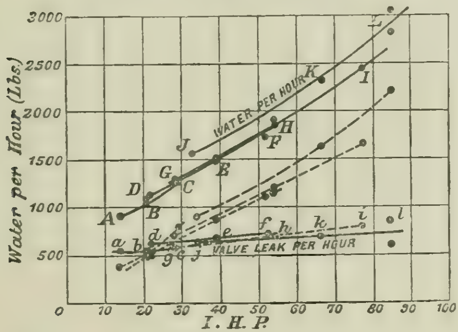
The cylinder jacketing alone gave a saving of 4·2 per cent. over the unjacketed engine, and the reheaters in addition a further saving of 2·5 per cent., making in this engine a total saving of 6·7 per cent. by the system of jacketing adopted.

Dr. J. T. Nicolson wrote that he thought that his former colleague Professor Callendar and himself had every reason to be gratified with Professor Capper's results, which might be said to have broadly confirmed the conclusions they had reached in 1896 with regard to the leakage of slide-valves. These conclusions had been met with a good deal of scepticism, especially on the part of steam-engine makers, who were usually unwilling to believe that their valves were capable of any leakage at all, much less the very considerable quantities which actually passed them. Only a few men like Colonel Crompton and Captain Sankey had given the matter any attention so far as he (Dr. Nicolson) was aware; and had come to the conclusion that, instead of aiming at reduction of cylinder condensation or reduction of clearance volumes and small refinements of that order, the thing that wanted doing was the improvement of the valves as to their tightness when in operation; either by better design or by heating the valve faces by jacketing in a suitable manner or by superheating the steam in the steam-chest. Perhaps they would, in future, as one consequence of Professor Capper's Report, hear less about cylinder condensation, Hirn's analysis and sharp points of cut-off, and more about valve leakage and the difference between engine feed and cylinder feed.

This Report was worthy of a much more prolonged and closer study than he (the writer) had as yet been able to give to it; and what he now wished to say had reference only to one or two of the more salient features. First he would desire to congratulate Professor Capper, if he might, on the admirable way in which he

had presented his data. He thought that in this respect the Report left nothing to be desired. He only wished, however, that Professor Capper had made some use of the method of condensation areas by observing the temperature of at least his clearance surfaces. He would then have been able to deduce the amounts of valve leakage under different conditions by subtracting the estimated condensation from the measured engine feed, instead of relying upon the assumption that leakage during an actual trial was practically the same as that during a valve-leak experiment. This was an important point, and one upon which he found himself unable to

Fig. 63.—*Simple Non-Condensing Engine Trials.*
McGill College, 1894–1899.



agree with Professor Capper's conclusions. He himself had found the working rate of leak was always greater and often very much greater than the experimental rate.

In support of this statement he had prepared a diagram, Fig. 63, giving the results of a series of careful trials he had made during the years 1894–1899 at McGill University with the same engine as used by Professor Callendar and himself on their experiments, to which Professor Capper had made reference. The results he now gave were, however, for double-acting trials, whereas in their Paper in the Proceedings of the Institution of Civil Engineers the engine was run only single-acting for the reasons there given. The engine was a high-speed simple automatic cut-off engine of 10½ inches diameter and 12 inches stroke, normal speed

TABLE 19.

Date, December 1897. 100 *lbs. per square inch. Unjacketed.*

1		M_0.	J_0.	K_0.	L_0.
2	Revolutions per minute . . .	60	100	200	300
3	Cut-off	0·4	0·4	0·4	0·4
4	Steam-pipe press. (abs.) lbs. per sq. in.	118·4	121·5	117·3	111·2
5	Corresponding temperature . F.°	340	342	339	335
6	Observed steam-pipe temperature F.°	336	339	336	331·2
7	Dryness by throttling . . .	0·98	0·98	0·97	0·97
8	Steam-chest pressure (abs.) lbs. per sq. in.	110	114·4	108·4	104·8
9	Corresponding temperature . .	—	—	—	—
10	Observed steam-chest temperature F.°	334·6	337·5	333·5	331
11	Clear surface temper. (cover end) F.°	321	320	321·3	322
12	,, ,, ,, (crank end) F.°	309	309	308	308
13	Exhaust-pipe press. (abs.) lbs. per sq. in.	—	15·5	16·0	—
14	Corresponding temperature . F.°	—	214·7	216·3	—
15	Observed exhaust-pipe temperature F.°	—	214·3	215	—
16	Condenser pressure (abs.) = barometric pressure	15·0	15·0	15·0	14·7
17	I.H.P.	20·1	34·9	66·6	84·6
18	Steam per I.H.P. per hour . lbs.	55·1	44·9	34·7	33·4
19	Total steam per hour. . . lbs.	1108	1536	2308	3075
20	Cushion steam per hour . . lbs.	—	88	184	290
21	Cylinder feed per hour by indicator at cut-off . . . . . lbs.	—	886	1662	2364
22	Missing quantity per hour at cut-off lbs.	—	738	830	1001
23	Estimated condensation per hour at cut-off . . . . . lbs.	—	110	133	142
24	Estimated valve leakage per hour lbs.	—	628	697	859
25	Leakage coefficient	—	6·28	6·90	9·54
26	Estimated cylinder feed per hour .	—	919	1626	2234
27	,, ,, ,, ,, revolution	—	0·153	0·136	0·123
28	Efficiency relative to Clausius cycle allowing for leak	—	0·63	0·69	0·67
29	Efficiency relative to Clausius supposing no valve leak	—	0·38	0·49	0·525

275 revolutions per minute. The trials were made at $\frac{1}{8}$, $\frac{1}{6}$, $\frac{1}{5}$, 0·3 and 0·4 cut-off, and at the three speeds, 100, 200 and 300 revolutions for each cut-off. Table 19 (page 332) gave the results, and Fig. 63 (page 331) gave three sets of curves representing them. The uppermost curves were ordinary Willans lines co-ordinating total engine feed (line 19 of Table) plotted on a base of I.H.P. (line 17). The lowest lines were valve leakages per hour, and the middle the differences.

Curves	JKL	referred to	0·4 cut-off,
„	GHI	„	0·3 „
„	DEF	„	0·2 „
„	ABC	„	0·125 „

and the 3 sets of points on each curve were for 100, 200 and 300 revolutions in the order named.

The leakages were obtained by finding the cylinder condensation at cut-off, by observation of wall temperatures, and the method of condensation areas, adding this to the indicated weight, and deducting this sum (which ought properly to be called the *cylinder feed*) from the whole amount used by the engine, called the *engine feed*, (allowance being, of course, made for cushion steam). It would be seen that the amount of this leak varied from 500 to 800 lbs. per hour; the steam used by the engine varying from 900 to 3,000 lbs. per hour. Upon reference to the Paper by Professor Callendar and himself, it would be found that the measured leak of the same valve, when tested with the ports plugged, and at the same pressure difference of 100 lbs. between steam-chest and exhaust pipe, was 300 lbs. per hour, so that in that instance, at all events, they had not found that the leak during actual working was the same as that during the valve leakage trial. It was two or three times as great. Professor Callendar and he had found that the temperature of the valve face had a very marked effect on the rate of leak; * and as, from actual observation of the temperature of the metal of the steam-chest face during both leakage and load trials, they had found that in the latter case this metal was much cooler,

* Proceedings, The Institution of Civil Engineers, 1897–8, vol. cxxxi, page 235.

(Dr. J. T. Nicolson.)

(as a result, probably, of the current of wet exhaust which flowed over it); this explained why the leak was greater during actual working than during a valve leak test with the ports plugged.

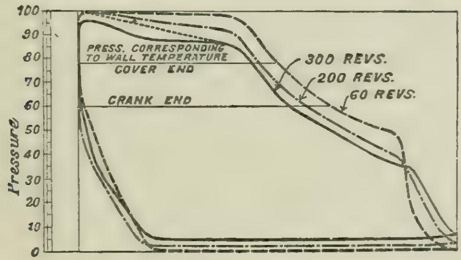
He wished Professor Capper had drilled some holes in his steam-chest face and noted the temperatures during leakage trials as compared with actual running. It would have been most instructive. Professor Capper's Table 5 (page 221) of the values of the leakage-coefficient for his valve gave for the mean value the figure 0·02. This was in surprisingly close agreement with the value for the two types of valve Professor Callendar and he had tested in Montreal, namely, 0·021 for the balanced valve of the small high-speed engine, and 0·02 for a valve with Meyer expansion plates on the low-pressure cylinder 18 inches diameter of the experimental engine designed by Mr. Druitt Halpin. Another valve of that engine which had been tested for leakage gave the same figure 0·019. It really would appear as if the leakage of slide-valves of small size and simple design was subject to the very simple law which Professor Callendar and he had found; and which might be stated thus: In slide-valves whose average "overlap" (or breadth of face opposing leakage) was one inch, there would be a leak of one-fiftieth of a pound of steam per hour per pound difference of pressure between steam-chest and exhaust pipe, for every inch of perimeter round the exhaust port, or about $\frac{1}{4}$ lb. per hour for every foot. This was the law of leakage of saturated steam across a moving valve with steam-ports blocked. In actual work he had produced evidence, Fig. 63 (page 331), that the leak would be twice as great; and that half a pound per hour would leak across every foot of perimeter having an overlap 1 inch wide, for a pressure difference of 1 lb. per square inch. The perimeter of the valve in question was 6 feet, and its overlap $\frac{1}{2}$ inch, so that according to this simple rule it ought to have leaked $\frac{1}{2} \times 6 \div \frac{1}{2} = 6$ lbs. per hour per pound difference of pressure, or 600 lbs. per hour at the pressure at which these trials were made.

They would also observe from the diagram that the leakage increased considerably with the power developed, whether that was obtained by diminishing the ratio of expansion or by increasing the

speed. This seemed reasonable, as in either case more exhaust steam would pass across the valve face per unit of time, producing a greater cooling effect at large than at small powers. This result also was contrary to Professor Capper's deduction that leakage *diminished* with speed (page 215). No doubt speed would have an effect on the laminar motion of the leaking water, similar perhaps to that of journal speed on lubrication, where there was found to be a critical speed below which the journal would not carry its oil into the bearing. But such a phenomenon would, in his opinion, be obliterated by the much more powerful contrary effect due to greater cooling of the faces at higher speed.

Fig. 64.

Indicator Diagrams affected by Speed.



He had also prepared three superposed indicator cards, Fig. 64, from this engine, showing the effect of variation of speed on the shape of the card at constant cut-off. The smaller weight of cylinder feed taken in at the high speeds which was obvious from these diagrams was not accompanied by a correspondingly rapid reduction of mean effective pressure; so that notwithstanding the increase of rate of valve with leakage speed, there was on the whole a diminution of the consumption with increasing speed, to a minimum which for this engine was reached at from 250 to 300 revolutions with late and early cuts-off respectively.

Professor Capper wrote in reply to the communications as follows:—Mr. Forward (page 323) had very rightly asked if the failure of lubrication occurred in all these cases of highest difference

(Professor Capper.)

of pressure, Fig. 32 (page 212), as the figure was plotted from the mean of all these experiments. His answer was that the leakage at the point where the valve seized could not of course be measured, but all these experiments were carried out directly after each other, and just at the end the valve seized. The scoring had probably been going on throughout all these measurements, and all these would therefore be probably affected by the burring up and raising of the valve. He could not say positively that this was so, as it was only when the valve seized that the effect was finally noticed, but, as there was a good deal of trouble experienced in getting regular results for some time before the seizure, it probably was so. As to the question of blocked ports versus experiments designed as Mr. Forward and indeed other speakers had suggested, he would not now fully enter. But he was distinctly of the opinion, after the careful investigation and experiments he had made, that any arrangement such as that suggested by Mr. Forward would lead to much greater errors in measurement than would be found to exist when blocked port experiments were corrected by the help of leakage area diagrams, such as those given in Figs. 34 and 35 (pages 218 and 219), though he admitted that these diagrams were drawn on tentative assumptions only. Yet both sets were drawn on the same hypothesis, so that the ratio between them was probably very closely correct. He did not think the flow of steam in actual working was likely to affect the comparative results more than shown on those diagrams. Experiments to determine whether this was so or not would be of great value, but were extremely difficult to carry out without introducing disproportionate errors.

In reply to Mr. Mason (page 329), during the whole series of experiments the lubrication in the cylinder was that described in the leakage tests as " siphon lubricator flowing freely " in addition to the sight-feed lubrication. To Dr. Nicolson's valuable remarks he had already alluded in his verbal reply. He would only add that the trials were well under way when Messrs. Callendar and Nicolson's Paper was published, and the whole of the trials would have had to be repeated if the scheme of them were to be altered, so as to work upon the basis of condensation areas. He quite agreed that it would have

been a very valuable addition if he had taken temperature at a number of points in the cylinder, but at the time the trials were begun it was not found practicable to do so. He acknowledged the omission, but claimed that this would have so largely complicated the experiments as to make their scope and period of incubation—already too large—extend beyond reasonable dimensions. He would endeavour to run special typical trials in the future under those conditions, so as to supplement the information contained in the present research.

To Mr. Kersey's very valuable contribution (page 324) he would only say that the laws he deduced and the results obtained by him from those laws, together with his comparison of these with the actual results obtained, were instructive. Their value would be greatly enhanced, if Mr. Kersey could find time to apply them to other experiments and see how far a general law could be evolved by so doing. He cordially agreed with the suggestion made that co-ordination of experiments was what was needed at the stage at which they had now arrived.

The Institution of Mechanical Engineers.

PROCEEDINGS.

April 1905.

An Ordinary General Meeting was held at the Institution on Friday, 14th April 1905, at Eight o'clock p.m.; Edward P. Martin, Esq., President, in the chair.

The Minutes of the previous Meeting were read and confirmed.

The President announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following fifty-six candidates were found to be duly elected:—

MEMBERS.

Beck, Arthur Edward, ...	Birmingham.
Cooper, Robert, ...	Dartford.
Hawkins, Thomas Whitehead, . . .	Rochdale.
Johnson, Frederick Dwight, . . .	London.
Leslie, Bradford, ...	London.
Molesworth, Walter Henderson, . .	London.
Niblock, Frederick, ...	Singapore.
Scott, Ernest Kilburn, ...	Sydney.
Sharp, Richard, ...	Workington.

ASSOCIATE MEMBERS.

Blake, Andrew William, ...	Monmouth.
Casson, Robert, ...	Manchester.
Coutts, David Alexander, ...	Aberdeen.

Evans, William,	Belfast.
Gibb, Maurice Sylvester,	Gateshead.
Gower, William Edward,	London.
Graham, Thomas,	Huddersfield.
Hird, Richard Thomas,	Ruabon.
Humphries, Albert,	Woolwich.
Ibbotson, William Frederick,	Sheffield.
Keevill, Robert Graham,	London.
Knox, Robert,	Colombo.
Lawson, Francis Malcolm,	Bristol.
March, Harry George,	London.
Marr, William Kay,	Alexandria.
McLachlan, James,	Hong Kong.
O'Neil, Rodolph Stuart,	London.
Seymour, Harold Walter,	Rotherham.
Shave, George James,	London.
Shaw, Cyril Morley,	Worcester.
Simms, Charles Edward,	Birmingham.
Smith, Ralph Vernon,	Nottingham.
Snow, William Raeburn,	Johannesburg.
Turnbull, Walter Alexander,	Bury, Lancs.
Turner, Vincent,	London.
Westacott, Percy,	Plymouth.
Williams, Albert Edward,	London.
Wilson, Robert Wood,	Paisley.

GRADUATES.

Alexander, Harold Montague,	Northfleet, Kent.
Andreadis, Angel Isidore,	Glasgow.
Cassels, Frank Lionell,	Buenos Aires.
Cole, Thomas Stephenson,	London.
Cornwell, William Daniel,	London.
Frank, Reginald Alexander,	Leeds.
Hearn, Ernest William,	Chippenham.
Hollingsworth, Frederick,	Darlington.
Jackson, George James,	Manchester.

Lacey, Onward Bayes, ...	Crewe.
Mail, John Stanley, ...	London.
Manners, Henry Briggs, ...	Nottingham.
Megirian, Joseph Jacob, ...	London.
Michelmore, Arthur John, ...	London.
Powell, Charles Russell, ...	London.
Rose, William Alexander, ...	Manchester.
Skidmore, Thomas Emmott, ...	Bristol.
Symons, Angus Bryant, ...	London.
Tillard, Thomas Atkinson, . . .	Cambridge.

The President announced that the following two Transferences had been made by the Council since the last Meeting :—

Associate Members to Members.

Finnie, William, ...	Singapore.
Jones, Arthur Dansey, ...	Horwich.

The President then delivered his Inaugural Address.

The Discussion on Professor Capper's First Report to the Steam-Engine Research Committee was resumed and concluded.

The Meeting terminated shortly after Ten o'clock. The attendance was 107 Members and 44 Visitors.

ANNIVERSARY DINNER.

The ANNIVERSARY DINNER of the Institution was held at the Hotel Cecil, Strand, London, on Thursday evening, 13th April 1905. The President occupied the chair; and the following were among the Guests who accepted the invitations sent to them, although those to whom an asterisk * is prefixed were unavoidably prevented at the last from being present.

*The Right Hon. Viscount Duncannon, C.B., C.V.O.; The Right Hon. Lord Stalbridge, Chairman of the London and North Western Railway; Major-General H. C. O. Plumer, C.B., Quarter-Master-General; Lieut.-Colonel Sir Percy Girouard, K.C.M.G., D.S.O., R.E.; Sir Thomas E. Fuller, K.C.M.G., Agent-General for Cape Colony; Sir William Arbuckle, Agent-General for Natal; Sir Robert S. Ball, LL.D., F.R.S.; *Sir Myles Fenton; Colonel C. M. Watson, C.B., C.M.G., Commissioner-General, Royal Commission for St. Louis Exposition; Colonel F. T. Clayton, C.B., Assistant Director of Transport and Remounts; Mr. E. Grant Burls, C.S.I., Director-General of Stores, India Office; The Hon. Alfred Dobson, C.M.G., Agent-General for Tasmania; Mr. E. A. Cornwall, Chairman of the London County Council; The Hon. H. A. Grainger, Agent-General for South Australia; *The Hon. J. W. Taverner, Agent-General for Victoria; Mr. W. H. James, K.C., Agent-General for Western Australia.

*Mr. Walter B. Clode, Master of the Merchant Taylors' Company; Mr. Arthur Field, Master of the Haberdashers' Company; *Dr. R. T. Glazebrook, F.R.S., Principal of the National Physical Laboratory; *Mr. J. C. Inglis, General Manager, Great Western Railway; *Mr. Daniel Irving, President of the Institution of Gas Engineers; Mr. Imre Kiralfy, Honorary Commissioner-General for the Liége Exhibition; Mr. Robert Matthews, President of the Manchester Association of Engineers; Mr. Frank E. Priest, President of the Liverpool Engineering Society; Mr. A. D. Southgate, Master of the Salters' Company; *Mr. Alderman and Sheriff T. Vezey Strong, Master of the Plumbers' Company;

Professor W. Cawthorne Unwin, F.R.S., Honorary Member; Mr. B. H. Warren, President of the Allis-Chalmers Co., Chicago; Mr. Nicholas J. West, President of the Society of Engineers.

*Professor J. O. Arnold; Mr. John Barr; Mr. James S. Beale, Institution Solicitor; Mr. Bennett H. Brough, Secretary of the Iron and Steel Institute; Professor David S. Capper; Mr. Dugald Clerk; Mr. F. L. Davis, Chairman, South Wales Conciliation Board; Captain Victor Ferguson; M. Evence Coppée; Mr. F. W. Harbord; Mr. A. T. Keen; Mr. Henry W. Martin; Mr. Robert A. McLean, Institution Auditor; *Dr. J. T. Nicolson; Captain H. Riall Sankey; Mr. Alfred Saxon; Mr. A. E. Seaton; Mr. Weston Stevens.

The President was supported by the following Officers of the Institution:—*Past-Presidents:* *Sir Edward H. Carbutt, Bart.; Mr. Samuel W. Johnson; Dr. Alex. B. W. Kennedy, F.R.S.; Mr. William H. Maw; Mr. E. Windsor Richards; *Mr. Percy G. B. Westmacott; Sir William H. White, K.C.B., LL.D., F.R.S.; and Mr. J. Hartley Wicksteed. *Vice-Presidents:* Mr. John A. F. Aspinall; Mr. Edward B. Ellington; Mr. Arthur Keen; *Sir William T. Lewis, Bart.; and Mr. A. Tannett-Walker. *Members of Council:* Sir J. Wolfe Barry, K.C.B., LL.D., F.R.S.; Mr. George J. Churchward; Mr. Henry Davey; *Mr. H. Graham Harris; Dr. Edward Hopkinson; Mr. Michael Longridge; Mr. John F. Robinson; Mr. Mark Robinson; and Mr. John W. Spencer.

After the President had proposed the loyal toasts, Sir William H. White, K.C.B., Past-President, proposed that of "Our National Defenders," which was acknowledged by Major-General H. C. O. Plumer, C.B., Quarter-Master-General, who said that mechanical transport was going to be the mainstay of the transport of the Army. It was, however, as yet only in its infancy, and its development must proceed slowly. What progress had been made had been due to the great engineering firms.

The toast of "Our Railways," which was proposed by Mr. J. Hartley Wicksteed, Past-President, was acknowledged by the Right Hon. Lord Stalbridge, Chairman of the London and North

Western Railway Co., who referred to the fact that at Euston the London and North Western Railway had many interesting documents, among them being George Stephenson's original estimates for the Liverpool and Manchester Railway, dated 5th February 1825. The rails were estimated at 35 lbs. per yard, and for a double line of 34 miles, at £16 10*s.* per ton, were to cost £61,710. The stone blocks for sleepers, put at 1*s.* 4*d.* each, were to cost £15,937 6*s.* 8*d.*, and the total estimate was £100,000, or about £11,765 a mile. Then the original "Rocket" weighed but a few cwts. compared with the engines of the present day. A Crewe express engine of 1852, alive today, though with many parts renewed, was attached to a coupé in which he often travelled at 60 miles an hour, and weighed 21½ tons. An engine of today weighed 59 tons 15 cwt. Once engines were built to suit the road, but the mechanical engineer had won the day, and now the road was built to suit him.

Mr. E. Windsor Richards, Past-President, proposed the toast of "Our Guests," which was acknowledged by E. A. Cornwall, Esq., Chairman of the London County Council.

Sir Robert S. Ball, LL.D., F.R.S., in proposing the toast of "The Institution of Mechanical Engineers," alluded to the fact that the meteorites were the finest nickel alloy suited for making armour-plates, and remarked that astronomers would wish Mr. Yerkes all success in his terrestrial tubes, in view of his gift to science, a marvel of mechanical engineering, namely, his celestial tubes at Chicago.

The President briefly responded to the toast.

ADDRESS BY THE PRESIDENT,

EDWARD P. MARTIN, Esq.

Gentlemen,—In the first place allow me to thank you for the great honour you have done me in electing me President of the Institution of Mechanical Engineers. It has become almost an unwritten law that the President of this Institution should, on taking up his duties, deliver an Address. It is only those who have occupied this position who recognise the difficulty there is in choosing a subject that, treated generally, may interest the Members. The difficulty arises from the fact that the Addresses already delivered have so ably covered the ground, that it is not easy to find new interesting subject-matter. Today a few minutes may be occupied by endeavouring to point out some of the improvements in mechanical engineering applied to the manufacture of iron and steel in the particular district, and generally during that period in which my experience has been gained—improvements which have, by their use and appliance, greatly increased the output, and reduced the cost of production, and have added so much to the comfort and well-being of the world. Referring to what has been done in the past sometimes points out how improvements may be made in the present, and in what direction to look for them.

The district referred to appeals to the mechanical engineer, as it was there that Trevithick in 1801 built the first railway locomotive, which ran on a tramroad leading from the principal iron works in Merthyr Tydfil to the head of a canal at a place then called Navigation, about 10 miles away. Dowlais then drew its supplies of fuel, ore, and limestone, from the hillsides adjoining. The iron ore was obtained from the argillaceous or clay band ironstone of the lower coal measures, and frequently from the same opening in the side of the hill the iron ore and the coal for smelting it were

brought out together. The same hillside formed a convenient platform for coking the coal, calcining the ironstone, as well as for feeding the blast-furnaces without any lifts. Iron works, however, cannot exist for 150 years on the same site without more or less exhausting the supplies and advantages which first caused that site to be chosen. Today, Navigation (now called by its Welsh name Abercynon) supplies coal to both the old Dowlais on the hills and the new Dowlais Works at Cardiff. The striking contrast that exists in the areas from which raw materials were formerly drawn for iron manufactures compared with those of today deserves attention. The fuel, instead of being drawn from the hillside at the back of the Dowlais blast-furnaces, is now brought from 3 to 12 miles away, and, instead of being practically quarried out from the side of the hill, is now being worked from pits upwards of 750 yards deep and 12 miles away, and the iron ore is almost all brought from abroad. The cost of the assemblage of material for the production of iron and steel is of great importance, as to produce a ton of pig-iron the weight of materials required varies according to the richness of the ore from $3\frac{1}{2}$ to 5 tons.

Old works were nearly always placed near iron ore, fuel, and limestone. Today, while many of them still enjoy proximity to one or other of these supplies, several of the most modern ironworks are situated at very considerable distances from the materials they use; and this is especially the case with some of the newest works in America situated on the shores of Lakes Michigan and Erie.

The foundation of our iron and steel industry rests upon the supply of good cheap iron ore, and we cannot lose sight of the fact that we are becoming more and more dependent for those supplies on importations from other countries; there are therefore few matters connected with our manufactures that should cause greater anxiety for the future. The demand for iron and steel continues to increase, and must increase, at a greater ratio year by year, and if a Royal Commission was considered necessary for investigating our supplies of coal, it is surely as necessary to look into the probable future supplies of our iron ore, as our imports are daily becoming larger, and the known reserves of first-class, cheap ores are diminishing, not

only in this country, but in many of the countries from which we draw our supplies. Even Spain is beginning to show that her wealth of iron ore is diminishing, though as this and other countries in Europe are being opened by railways, far greater supplies are forthcoming, and, fortunately, the enormous deposits of Norway and Sweden are being rapidly and largely developed. Recently, processes for concentrating what would otherwise be inferior ores are being made on an extensive scale, and will shortly materially assist our supplies, and help to meet the increasing demand for first-class ores. The very important deposits of Minette ores in French Lorraine, Luxemburg, and Germany, form another of the greatest reserves of iron ore that Europe possesses. It is fortunate for the world that the Thomas-Gilchrist process has come to our assistance, as it enables these large reserves of second-class and other inferior ores to be utilized for the production of steel. This process already provides a very large proportion of the world's requirements, and will continue to increase in the future at even a greater rate than it has done in the past.

This question of the rate of increase is one that is generally not fully appreciated: my late friend, Abraham S. Hewitt, prophesied as far back as 1872 that in 1890 the world's production of pig-iron would reach 28 million tons; the quantity produced in that year was 27,630,000 tons. He also said that at the beginning of the 20th century the world's production of pig-iron would be more than 40 million tons; it was 40½ million tons. If the world's requirements continue to increase at this rate, we may expect that the world's production of pig-iron 17 years hence will reach about 80 million tons. This means roughly that 160 million tons of iron ore per annum would be necessary to meet the requirements of the world. These figures are difficult to grasp, and perhaps an illustration would bring home to us better what that quantity really means. The Bilbao district began exporting iron ore about 27 years ago; its total output from that time amounts to about 110 million tons, and the world would therefore require, always supposing the present rate of increase continues, about a Bilbao and a half per annum to provide its make of pig-iron. Where is this to come from? Fortunately,

our cheap steel enables us to build cheap vessels, and so obtain cheap freights, and with cheap freights there is no doubt that all our requirements will be amply met, as we have the whole world from which to draw our supplies; even now part of those supplies are being drawn from as far as Cuba. For special manganiferous and other ores, India on the east, South America on the west, and New Caledonia in the Antipodes help to furnish our wants.

It has been pointed out how very important a cheap supply of iron ore is, as without it the cost of our ordinary everyday wants must be increased, much to the detriment of our general welfare and progress. One of the most important factors in obtaining both large supplies of, as well as cheap, ores, is, as has been said, cheap transport. Our recent visit to the States will have shown us the important advances being made there in dealing with the handling and transport of iron ores, especially on the Great Lakes. Although most of the iron-making districts in Europe have for a long time past been dependent, for good hematite ores, on distant countries and on low freights, up to the present few or no vessels have been built for the special purpose of carrying iron ore, such as have been, and are being, built in America. There, vessels of the largest size, carrying upwards of 10,000 tons of ore, 560 feet long, 55 feet wide, and 32 feet deep, have been constructed without bulk-heads or divisions, and with holds in the form of a hopper measuring 409 feet long, 43 feet wide at the top, and 25 feet wide at the bottom. This system of building leaves the whole cargo exposed, so that the ore can be easily and rapidly unloaded by the Hewlitt and Brown machines or shovels. By the aid of depôts or bins these vessels are loaded in an almost incredibly short space of time. In August last the "Augustus B. Wolvin" was loaded with 10,345 tons of iron ore in 1 hour and 29 minutes; but what is still more remarkable is, that a cargo of 9,945 tons of iron ore was unloaded out of this same vessel in July last in 4 hours and 6 minutes. This was done practically without manual labour, as, although there were 50 men in the hold to work away the ore from the sides of the vessel, their work was confined to the last hour, when the ore at the sides was brought nearer the hatches, so as to facilitate the unloading. No doubt the condition of

the ore, which is fine, lends itself considerably to this rapid rate of working. It is by such work as this that the cost of freight can be greatly reduced, as the capital locked up in the vessel is continually on the move earning a return, the vessel being almost altogether occupied either in bringing ore in or returning back for another cargo. Figures such as these are not approached on this side, and perhaps the best example we can show is that of loading coal at some of our Bristol Channel ports. At the Roath Dock, Cardiff, 6,700 tons of large coal have been put on board a vessel in 11 hours. In another case 11,670 tons of coal were put on board in 3 hours and 45 minutes. This coal, however, had all to be unloaded from wagons, and was not run out from bunkers, placed at a higher level.

Our American friends, when called upon to deal with special problems, recognized the advantages which can be obtained by using specially designed machinery. They deal with the problem without preconceived notions, and are perhaps less bound by old ideas than we are on this side. As an instance, the Mesabi ore is almost entirely raised and filled at the mines by Goliath navvies into wagons brought to the face of the workings. These wagons are run from the mines to the bins at the loading port; from the bins the ore is run out into specially built vessels, and on their arrival at the other side it is unloaded by special machinery, and carried to the works in Pittsburg in special railway trucks carrying 50 tons each, from which the ore is again dropped into depôts at the blast furnaces, filled into skips, and charged into the blast furnace, thus producing pig-iron with a minimum of manual labour, and practically without a shovel being used.

Coke.—Abraham Derby first used coke in a blast-furnace about 1735, and the improvements in coke-making were few and slow from that time until about a century later, when various kilns and ovens of different descriptions were brought into use. A little later, heating-flues were introduced in the bottom of some of these ovens, and about 1860 the waste heat from coke ovens was being extensively used for the purpose of raising steam. To the brothers Appolt is due the system of coking coal in a closed retort oven, which was first used about that time. This system has been improved upon by

Coppée, Simon Carvés, Otto Hilgenstock, Kopper and others, all of whom have recently contributed to perhaps the greatest improvement that has taken place in coking, viz., the utilization of by-products formed in the manufacture of coke, by which its cost has been considerably reduced.

Blast-Furnaces.—At about the period referred to, Neilson's great invention of hot blast was used on all blast-furnaces, except where cold-blast iron was specially made. Blast-furnace gas for heating purposes had been drawn off by Palmer Budd, at Ystalyfera, as early as 1836, but it was not until some time after, 1850, when Parry, of Ebbw Vale, had introduced his plan of the cup and cone, that blast-furnaces in this district were generally worked with closed tops. The outputs were small even as late as 1853, when seventeen blast-furnaces at Dowlais working on raw coal only produced 1,751 tons of pig-iron per week.

Improvements made about this time were gradual, and principally consisted of increasing the power of the blowing-engines, the pressure and heat of the blast, and the size of the blast-furnaces. But, after the introduction of the Cowper and Whitwell regenerative hot-blast stoves, by which the heat of the blast was greatly increased, an impulse was given in the economy of fuel and also in outputs. About 1880 our American friends, among whom were Jones, Gayley, Kennedy and others, did much towards further increasing the makes of blast-furnaces. Eight years later, or about 15 years ago, the new Dowlais-Cardiff blast-furnaces were designed, and, while with the old plant at Dowlais a maximum of 1,000 tons had been made in one furnace in one week, at the Dowlais-Cardiff furnaces an output of over 2,300 tons has been produced in the same period. This was a great increase on the make of the seventeen old Dowlais blast-furnaces, but this increase is small compared with the make of some of the furnaces we have recently visited in America. At the Duquesne furnaces 793 tons of pig-iron have been obtained from one blast-furnace in one day, a weekly output of over 5,000 tons, and a monthly output of 26,659 tons! These huge makes have been obtained with a saving in fuel and reduced labour and cost, and such economies are largely due to the improved

mechanical appliances used, viz., the introduction of larger and more powerful blast-engines, greatly increased pressure and heat of blast, the use of self-loading skips operated below bunkers by electricity, appliances for regulating the distribution of the charges at the top of the furnace, cooling arrangements for preventing the wear and tear of the linings, and appliances for disposing of both the iron and slag produced. Any iron not taken away in a molten state for use in the steel works is either cast upon machines or on sand-beds in the usual way, thence handled and stocked by cranes, and broken up by mechanical breakers as required. The slag is usually either taken away molten in ladles, or by disintegration in water reduced to a condition that permits of its being handled easily. These and other improvements have assisted in increasing the regularity of the product, diminishing its costs, and reducing the employment of manual labour.

A new process which seems to promise remarkable results is Gayley's application of dry-air blast to the manufacture of iron. Those who have had an opportunity of seeing this process at work expect further reductions in the amount of fuel required to make a ton of pig-iron. It is not a little remarkable that as early as 1825 the question of the effect of moisture in blast was, with other matters, the subject of a Paper read by Neilson and discussed by the Philosophical Society at Glasgow.

Still further economies may be expected by the use of steam-turbines for blast-engines, but above all by the introduction and utilization of blast-furnace gas, and gas from the manufacture of coke, for the purpose of raising power for driving blast and other engines; this is now being followed with the greatest possible interest. The difficulty of cleansing the gas from blast-furnaces has now been overcome, greatly reducing the wear and tear of the engines; and blast engines, worked by blast-furnace gas, may now be said to be beyond the experimental stage. Many plants, especially on the Continent, are being entirely driven by engines worked with blast-furnace gas, and it is to these and other improvements that we look to reduce still further the cost of making pig-iron. It is a question whether the manufacture of pig-iron may not some day be

reduced to a by-product in the making of gas for producing power in electrical and other central stations.

The importance of central electrical stations for power and light, from which they can both be supplied as rapidly and as easily to the community as gas now is, is only beginning to be appreciated, and the time may come when we may be able to transmit the power thus developed to distant consumers without conductors, as Marconi does his messages! The enormous stride from the telegraph to the telephone is not much more surprising than this would be.

An important invention of great utility, not usually given the attention it deserves, is that of Captain Jones for mixing and desulphurizing molten pig-iron for the production of steel. The bringing together, and mixing in a large receiver containing several hundred tons of molten metal from the different blast-furnaces, often producing different grades and qualities, has contributed greatly to the ease and regularity with which the Bessemer process can be worked.

Puddling.—Before puddling was introduced, malleable iron in the South Wales districts was produced by what was called the Welsh or Lancashire process, which consisted of working molten pig-iron on a charcoal hearth with blast; this process continued in use in that district for the production of bars, for making best charcoal tin plates, up to a short time ago, when it was practically ousted by the manufacture of Bessemer and Siemens steel bars. The world owes a debt to Henry Cort for his invention of puddling and of rolling in grooved rolls, and it is only within the last month that an American ironmaster has erected to Cort's memory in Hampstead Parish Church, where he was buried in 1800, a monument at the unveiling of which the Institution was officially represented.

In former years, as I have stated, improvements in the manufacture of iron grew slowly, and generally an iron works with blast-furnaces, puddling forges, and mills, put down by a man's grandfather, did not require serious alteration even by the grandson, until after the arrival of the age of steel. The puddler at that time practically regulated the output of the various iron works, and

puddling remained much in the same condition as when invented by Cort, except that Rogers had introduced the cast-iron bottom for puddling on, and boiling pig-iron was practised instead of working refined metal. Many serious attempts were made to lighten the very heavy labour of the puddler, and to increase the output. Tooth, Menelaus, and Danks were almost successful; but today, though there is still a large amount of puddling done, little has been effected towards assisting the heavy work of the puddler.

With the introduction of steel, general improvements have been numerous and continuous, and perhaps one of the greatest taxes on the iron and steel maker of today is the frequent sacrifices he has to make of what is termed old plant to make room at great expense for machinery that is newer and up to date. Most of these changes have taken place since about 1860, but when discussing the inventions made in this and other countries, it should not be forgotten that most of them originated here, though it would not be easy to apportion the credit due to the several men connected with the progress made in the various mechanical appliances used in the production of iron and steel.

It is difficult to appreciate what the world would be today but for the inventions of Bessemer and Siemens. Without them, it is a question whether all our present railways would have been built, as the difficulty of supplying iron rails would probably have taxed the trade of this and other countries beyond their powers. In any case railways would not have been able to carry, with the safety, ease, and at the great speeds they do, the enormous traffic they now have to deal with. The work of keeping the switches and crossings of our large terminal stations in repair would not be easy without these rails. The durability of steel rails is such that, notwithstanding the enormous increase of railways, rail makers have frequently to find other uses to keep their men and mills fully employed. It is the introduction of the Bessemer process, followed later on by the Siemens process, which has caused the great changes and improvements that have been made in the manufacture of steel. Bessemer gave his process to the world at the British Association meeting at Cheltenham in 1856, and within a few days of his

reading that Paper, experiments were made at Dowlais by Menelaus, Williams and Riley, which were so encouraging that Bessemer was invited to Dowlais to carry out his process. At that time Bessemer was under the impression that his process could treat any class of pig-iron with success, and he was not aware that pig-iron containing any large amount of sulphur and phosphorus could not make good steel. Bessemer has admitted this in writing to myself and others. Unfortunately, when he made his first experiment at Dowlais, a convenient refinery was placed at his disposal which happened to be fed from a blast-furnace making cinder pig-iron. The result of the experiment was most discouraging; the ingots could scarcely stand the heating in the furnace, and fell to pieces in the rolls. An analysis of one of the ingots now at Dowlais is as follows:—

Carbon	0·06
Manganese	nil
Silicon	0·01
Sulphur	0·276
Phosphorus	1·930
Arsenic	0·010
Iron (by difference)	97·714

After Bessemer had discovered that it was necessary to work with pig-iron as free from phosphorus and sulphur as possible, he followed up his invention by introducing special mechanical devices for dealing with his process, and few inventions have been presented to the manufacturer so fully equipped as was Bessemer's. His arrangements for working his plant by hydraulic power practically remain the same as when he started them. His converters, his blast arrangements, his casting ladle, together with the cranes, although in some degree improved upon, remain much the same as they were when he first brought them out. Indeed, but for his great invention of steel-making, Bessemer would have shone as a first-class mechanical engineer. The converters used in his process today have been largely increased in size, as it has been found that steel ingots of large size can be dealt with, by the aid of mechanical appliances, with much greater ease, less manual labour, and less cost than was the case in rolling iron rails of a few cwts. weight in former years.

The adoption of driven feed-rollers at the rolls, improvements in shears for cutting ingots, the enormously increased power and speed of the engines, the heating of the ingots in vertical furnaces, the convenient placing of the cogging, roughing, and finishing rolls, have all tended to increase the output of the mills, so much so, that a month's make of the old iron rail mills is now surpassed by the make of one of the modern steel rail mills in a turn of twelve hours.

Cort's invention of rolling bars is only 120 years old, and about that time the engine invented by James Watt was rapidly coming into use. Up to that time, bars were drawn out under tilt hammers—a costly and laborious process. The first wrought-iron rails are said to have been rolled at Pen-y-darran Iron Works, Merthyr Tydfil, and as an instance of how conservative engineers were in those days, although it would have been far easier and simpler to have rolled the rails as straight bars, they were rolled fish-bellied every three feet, in imitation of the old cast-iron fish-bellied single-headed tram plates. The men named them "jumpers," as they came out of the rolls in a very erratic manner. The rolling of iron rails brought in the use of what was then considered steam-engines of the heaviest description. A fair example is one erected at Dowlais, called the Big Mill, built more than 75 years ago, and is still working. It is a beam engine with a cylinder 40 inches in diameter and 8 feet stroke, geared and driving the rolls about 60 revolutions per minute. It may interest you to be told that it was in this rolling mill that the first Bessemer steel rail was rolled from a steel ingot 10 inches square, which had been made at Baxter House, London, by Bessemer, from Blaenavon cold-blast pig-iron. The following is an analysis of a piece of the rail in the author's possession:—

Carbon	0·080
Manganese	trace
Silica	,,
Sulphur	0·162
Phosphorus	0·428
Arsenic	trace
Iron	99·330

It is of great interest to note that this rail was made without the addition of any manganese.

The Big Mill engine was followed by the erection of some very large coupled beam engines, having cylinders 45 inches in diameter and 10 feet stroke; the driving wheel was 25 feet in diameter, the teeth 8 inches pitch and 2 feet wide on the face, and worked with a boiler pressure of 50 lbs. to the inch. This engine was built with the intention of driving two mills, one an ordinary rail mill, and the other a mill for rolling girders, in which four rolls were set in one housing, the two middle rolls being on the same level, and the bar being passed to and fro without the engines being reversed. The erection of this mill practically marked the end of large engines for the purpose of rolling iron rails. When the Bessemer process began to be worked in 1865 at Dowlais on a large scale, these engines were used to cog the ingots and then roll them into rails. Cogging or rolling steel ingots was first introduced at Dowlais about 1866, and in 1879 these engines were replaced for the purpose of cogging by more modern coupled horizontal reversing engines—an invention of one of your previous Presidents, John Ramsbottom, and further improved by another President, Windsor Richards. Soon after that time hammering ingots for making steel rails practically ceased, although this was hardly ever done in America owing to the early inventions of Fritz.

What Bessemer did for the rail maker Siemens a few years later did for the plate and structural steel maker. When making steel by the Siemens process first began, furnaces of 4 or 5 tons were usually used; today, furnaces of 40 to 50 tons are not uncommon, while there are many very much larger. The production of Siemens steel in this country has rapidly increased, so much so that open-hearth steel has, during the past year, almost doubled that of Bessemer. The Thomas and Gilchrist invention of basic steel has increased the make of Siemens basic steel to a much greater extent than Bessemer basic steel, notwithstanding the large use of the Bessemer process for making steel on the Continent. Next to the invention of Bessemer and Siemens, the invention of the Thomas and Gilchrist basis process is probably one of the greatest

improvements that has been made. The world's production of steel ingots in 1902 was about 33,350,000 tons, of which no less than 14,290,000 tons were of basic steel, and the whole of this has been made from a quality of pig-iron that could not have been profitably used by the original Bessemer or Siemens process.

Another invention from which much may be expected is the Talbot continuous steel process, which enables large outputs to be produced, and from a quality of pig-iron not sufficiently good for making Bessemer and Siemens steel. Furnaces of enormous size have been erected for this process, some containing as much as 200 tons of molten metal, and turning out an average of over 1,200 tons per week. The value of this system is that it enables pig-iron of various qualities to be used to advantage, and at the same time to produce a high-class quality of steel. It will not surprise those who have had an opportunity of watching this process, that it and similar methods may affect the manufacture of steel in as great a measure as the adoption of the Siemens furnace has affected the output of the Bessemer.

The improvement in mills rolling steel today, compared with the mills rolling iron rails in the sixties, is very striking. The makes of iron rails of about 600 tons per week has now been raised to over 10 times the amount of this rate. Instead of the old iron rails weighing about 4 cwt. and being rolled in lengths of 24 feet, ingots are now cast weighing upwards of $2\frac{1}{2}$ tons; they are rolled into lengths of more than 200 feet, and are cut to any required length from 20 to 60 feet. No doubt the principal cause of the increased output is due, among other things, to the larger number of rolling-mill engines employed, as, in the old iron mills they never exceeded two, viz., an engine for the blooming and an engine for the finishing mill, whereas in modern steel-rail mills it is usual to have at least three engines, one for the cogging, another for the roughing, and another for the finishing rolls. In some cases this work has been divided among four or even five engines. The mill at Dowlais is laid out with three engines, and is capable of turning out, if supplied with steel, about 5,000 tons of finished rails per week; but what is peculiar is, that this quantity of steel can be turned out at this mill

with fewer men than would have been necessary for the making of 600 tons per week of iron rails in the mill that occupied practically the same ground and was under the same roof. At the cogging rolls a bloomer and two boys working the live rollers and manipulators, deal with the whole weight of the material to be rolled. The bloom is then transferred to the roughing train, where no hand-labour whatever is used in turning the bar or moving it from one groove to another, this work being done by the live rollers on each side of the rolls, assisted by an Evans and Lewis manipulator, the whole of which arrangement is worked by two boys. The bloom, after being roughed out, is transferred to the finishing train, where two other boys working the live rollers, and with an Evans manipulator, finish the rail. Two men look after the roughing and finishing trains, watch the section, attend to the adjustment of the rolls and have little or nothing else to do. At an iron mill there were at least twelve or thirteen men employed for one-eighth of the output.

In addition to the engines being made much more powerful than formerly, running faster, using higher pressures of steam, assisted by driven rollers and manipulators, improved shears for cutting ingots, quick saws for cutting rails to lengths, skids for handling the hot rails on the cooling beds, straightening presses, drills, grinds, and other tools for finishing the rails, these with other mechanical appliances have made it easier to roll 5,000 or 6,000 tons of steel rails per week than it was formerly to make 500 or 600 tons of iron rails per week.

Reference has already been made to the probable improvements to be effected by the use of blast furnace gas in gas-engines, but one of the latest ideas, which is about to be carried out on a very large scale with regard to rail mills, is, that the roll shall be driven by motors, whose power will be developed by gas-engines driven by the gas from the blast-furnaces. The power thus obtained will be delivered as current to motors at the rolls, to which they will be connected by gear, and will supplant the present enormous steam-engines now in use for driving these rail mills.

The improvement in plate mills for rolling steel plates is as great as that which has taken place in the steel-rail mill. Five and thirty years ago a plate mill in this district making 100 tons of plates per week was considered to be doing fair work. Today, a mill making a similar class of steel plates but of much larger area is turning out easily about eighteen times that quantity, and in America the enormous make of 450 tons has been rolled in 12 hours. These large quantities are again due to improvements brought about by mechanical appliances, for handling large ingots or blooms weighing as many tons with greater ease than was formerly the case when the weight of the ingots was only cwts. handled by manual labour. Reference has not been made here to the large masses used for producing heavy armour plates or shafts. What this advance means may be shown when it is called to mind that Krupp was considered to have done marvellous work in showing an ingot weighing about a couple of tons at the Exhibition in 1851, though it must not be forgotten this was made from crucible steel. Today ingots can be made of almost any weight, and their size is practically governed by the power of the appliances used for moving them. At the St. Louis Exhibition a model was shown of a cylinder weighing 150 tons which had been cast in nickle steel for a 10,000-ton forging press. Ingots of 60 tons weight for armour plates are not infrequent. In plate mills the improvements in rolling engines, the adoption of universal rolling trams, enormous hot slab shears, cranes of all descriptions for handling, charging, and drawing material from heating furnaces, cooling and straightening roller tables, cold shears capable of cutting plates up to $2\frac{1}{2}$ inches thick, cooling floors fitted with castor rollers by which these heavy plates are easily moved, have all contributed to the great outputs of steel plain rolling mills, and have enabled steel plates to be produced at prices not dreamt of in former years. This, in its turn, has had a beneficial effect on ship-building, so that vessels are today being built of this splendid material at a lower cost than perhaps at any previous history of the trade. The reduced price of plates has again re-acted on the cost of vessels. A former President, Sir William H. White, has pointed out the great advantages the use of

steel has conferred on the shipbuilder. Indeed, few improvements can be mentioned which do not in some way favourably affect either the cost or the output of materials required by mankind.

While referring to the improvements in making steel plates and rails, one must not omit to mention the great strides made of late years by hydraulic forging. Presses of 5,000 and even 10,000 tons are not uncommon, and for working large masses the hydraulic forging-press seems to have almost replaced the steam-hammer. A well-known name in this Institution, Benjamin Walker, had much to do with the progress of this invention. While considering forging of large masses of iron and steel, it is not easy to forget the impression caused by first seeing the Iron Pillar at Delhi. This column of wrought-iron, which is 16 inches in diameter, of which 22 feet are above the ground, and which is said to be 50 feet long and weighing about 18 tons, is finished perfectly round and smooth with an ornamental top, and was made many centuries ago from iron produced direct from the ore, and built up piece by piece. Remembering the lack of facilities men had in those days for first forging and then welding together such an enormous mass makes one wonder at the ironworker of those days, who must have possessed engineering ability claiming the admiration of our own times. It is questionable whether the whole of the iron works of Europe and America could have produced a similar column of wrought-iron so short a time ago as the Exhibition of 1851.

Another matter that should be mentioned is, the progress made in electrical smelting. Although this may not be applied largely to ordinary steel making, there is little doubt that it has a large field open before it for the production of valuable iron alloys.

In the few remarks made, frequent comparisons have been drawn between what is being done on this side of the Atlantic and what is being done in the States. The recent visit of our Institution, under the guidance of its able Past-President, Mr. Wicksteed, to that great country, must be held as the reason for this. But although calling your attention to their large outputs, it by no means follows that methods and outputs so suitable and successful in the States, with its immense area, great population, and protected markets, would prove

as successful on this side. The United States are not infrequently referred to almost as if they were of the size and importance of English counties, not as they really are, of the size and importance of European countries. Great Britain, with its area of 120,000 square miles and 43 million inhabitants, cannot compare with the United States with its 3,622,933 square miles (practically the size of Europe), with a population nearly double that of Great Britain, and increasing at the rate of nearly 2 millions every five years. The requirements of such an enormous new country, with such an active population, can account for a new steel works being laid out to produce 7,000 tons of pig-iron daily, with gas-engines to provide 40,000 horse-power, and steel works to produce 1 million tons of steel ingots per annum. In this country the great question would be, not so much how to produce these large quantities, as to dispose of them profitably when they were made. The system in the States of specializing various classes of mechanical engineering has struck most of us. May this not be principally due to the great advantage they possess of having an enormous protected market at their doors?

Looking back to the numerous inventions that have recently taken place, one may perhaps regret having lived one's life too soon, as, notwithstanding all the grumbling and growling that goes on in this world of ours, we are enjoying comforts such as our ancestors never dreamt of, and we move from place to place with speeds that were only imagined in the "Arabian Nights."

The engineer's life is no doubt a strenuous one, but one of the rewards of the mechanical engineer is that whatever improvements he may make to benefit himself, he is certainly benefiting the rest of mankind. Every labour-saving device has contributed towards easing the toil of thousands, and has at the same time greatly increased the opportunity of employment, and the well-being and happiness of the world.

Mr. WILLIAM H. MAW, Past-President, said there were occasions —he admitted not many—when it was not only justifiable but desirable to ignore the prerogatives of the Chair, and therefore without even going through the pretence of obtaining the permission of the President he would ask the members to join him in according to Mr. Martin a most hearty vote of thanks for the Address which he had just delivered. Mr. Martin had very wisely devoted his Address to a consideration of the developments of that branch of mechanical engineering in which he had been himself chiefly engaged, and by that means he had not only produced an Address of great permanent value, but an Address which obtained added interest from the fact that the development which he had traced was one in which, if his modesty had allowed him to say so, he had taken a very prominent position. He (the speaker) was glad to see that the President had referred to the indebtedness of the mechanical engineer to his old friend, Sir Henry Bessemer, and it was especially appropriate that he should have done so, as the present year happened to be the Jubilee of the great Bessemer patent, Bessemer having taken out his chief patent for the process with which his name was associated in June fifty years ago. Thus the Address was delivered within two months of the time when that great invention was brought before the world. Lord Stalbridge, on the previous evening in a very interesting speech (page 344), had spoken of George Stephenson's estimate of the rails for the Manchester and Liverpool Railway, rails at 35 lbs. per yard costing £16 10*s*. a ton. It was interesting to know that, thanks to Bessemer and those who followed in his footsteps, the heavy steel rails required for a first-class permanent way of the present day could be turned out at a somewhat less cost per yard than the old light iron rails for which Stephenson estimated. The Address was full of very instructive and suggestive points, and, if time permitted, he should like very much to dwell upon some of them, but he had received a hint that time was very valuable that evening on account of the important discussion to follow, and he

would therefore say nothing further, except to ask the members to join him in the most hearty vote of thanks to the President for the admirable Address he had just delivered.

Mr. J. HARTLEY WICKSTEED, Past-President, had the privilege accorded to him of seconding the vote of thanks. He felt he had no right to do so with Mr. Windsor Richards, senior Past-President, sitting beside him, but he supposed Mr. Richards felt, as also did Mr. Maw, that he (Mr. Wicksteed) would be very much gratified at being able to express the pride and pleasure he had that evening in listening to his successor, and in feeling that the Presidency of the Institution was so upheld by Mr. Martin that it would redound to the credit of all those who had previously occupied the Chair. He felt that the President had given an epitome of a life's work. The whole of the information had come within Mr. Martin's intimate personal knowledge, and that was what made it so vivid and interesting to listen to. For those reasons it gave him great pleasure to be the vehicle of seconding the vote of thanks which he was sure all the members wished to have an opportunity to express. He was greatly interested in the little parenthesis referring to Cort's invention. When he was in America he visited Mr. Morgan, of Worcester, who almost idolized the memory of Cort, and it was Mr. Morgan who had prepared something in bronze for the tomb of Cort, in order that young men might look and see in what honour a man was held who had done the things Cort had done for the benefit of mankind; and that, although the results of his labours might not have enriched the inventor himself, yet he was held in honour by succeeding generations.

The Resolution was carried by acclamation.

The PRESIDENT thanked the members very much for their hearty reception of the few words he had addressed to them.

CONVERSAZIONE.

A CONVERSAZIONE took place at the Institution on Thursday, 11th May 1905, when the Members and their friends were received by the President and the Misses Martin. During the evening the band of His Majesty's Scots Guards played a selection of music, and vocal music was rendered in the Library. Mr. Francis Fox gave a short description of the Simplon Tunnel, and illustrated it by lantern slides. The number of Guests was about 850.

PHOTOGRAPHS OF CUTTING-TOOLS IN ACTION.

By Mr. J. F. BROOKS, *Associate Member*, of Leicester.

[*Selected for publication.*]

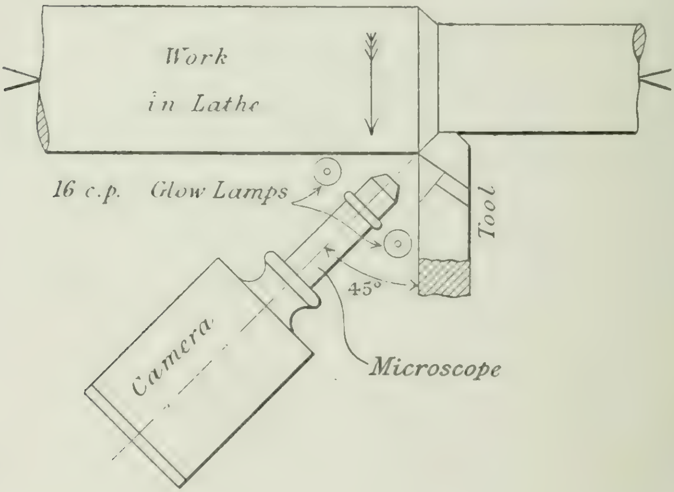
Explanatory Note.—The forty photographs of tools in the act of cutting various metals, Plates 8 to 12, were taken by the author at the Municipal Technical School, Leicester. The tools have cutting angles varying from 90° to 45°, and take different depths of cut with generally a clearance angle of 7·5°. They are represented cutting cast-iron, Plates 8 and 9; cast-steel, Plate 9; mild steel, Plates 10 and 11; gun-metal, Plate 12; wrought iron, Plate 9; and copper, Plate 12. The photographs were taken with the work stationary on account of the long exposures which were necessary. The tool was not, however, altered in any way; and often the cutting was allowed to proceed until a characteristic view was obtained. The method of taking the photographs is shown in the accompanying Fig. (page 366), and on Plate 7.

The work having been placed in the lathe and the tool adjusted, the microscope was put in position and the camera was then brought to the tube of the microscope. The tool was so ground that the cutting edge made an angle of 45° with the axis in the plan. On the left side the stock was removed, so that the view presented was fairly normal to the line of vision and at right angles to the cutting edge. What is actually shown, therefore, is an end view of this cutting edge, and what is called the depth of cut is really the rate of traverse as seen at an angle of 45°. The ordinary depth of cut, as understood in the workshop, made no difference to the picture $\frac{\text{Depth of Cut as seen}}{\text{Traverse}} = \frac{1}{\sqrt{2}}$. The magnification due to the microscope was about six diameters, varying somewhat with the position of the camera.

The object of taking the photographs was merely to keep a record of what was seen with a view to answering the questions: How does the tool act? What is the influence of the material, cutting angle, depth of cut, and speed of cutting? The action of these tools cannot be described as pure cutting; the chip is formed in many ways. Compression, shearing, splitting and tearing, all play a part; sometimes singly, sometimes together. The action seems to be most satisfactory when the extreme cutting edge causes

Method of Taking the Photographs.

PLAN.



a gradual and even shear of very thin laminae. Any departure from this action involves, either crushing of the material in front, and consequent deformation of the finished surface, or an indefinite splitting which is not directly controlled by the tool edge. In the first case the forces must be excessive, in the latter they must fluctuate considerably.

As might be expected, each material has its distinct characteristics. The property mainly influencing the mode of separation is its plasticity, or the ease with which its crystals slide over each other.

If the forces at the tool point are weighed, then the tenacity, elasticity, &c., of the material will alter their magnitude. The way in which separation of the shaving is effected often varies in the same bar, and probably the study of this will form a very searching test for homogeneity in a material.

The cutting angle requisite to produce the above ideal condition varies with the thickness of the shaving; and indeed with very thick shavings this condition may be unobtainable, on account of the shearing force necessary to cause sliding along the particular line of slip being greater than the crushing resistance of the metal. The material, cutting angle, and thickness of shaving are closely connected, and the simplest method of investigation is to take photographs of the actual conditions. The effect of cutting speed cannot be dealt with in this way. From observation, however, it appears that the angle at which slipping or shearing takes place is fairly constant for all ordinary speeds.

The quality of the material operated upon is as follows:—

Cast-iron, Plates 8 and 9: combined carbon, 0·315 per cent.; graphite, 3·26 per cent.; silicon, 2·193 per cent.; sulphur, 0·039 per cent.; phosphorus, 0·991 per cent.; manganese, 0·721 per cent.

Average crushing stress per square inch 28·3 tons.

Mild steel, Plates 10 and 11, "Acid Bessemer": carbon, 0·22 per cent.; manganese, 0·936 per cent.; silicon, 0·047 per cent.

Gun metal, Plate 12: copper, 90 per cent.; tin, 8 per cent.; zinc, 2 per cent.

The Paper is illustrated by Plates 7 to 12, and 1 Fig. in the letterpress.

NOTE ON A TEN-WHEELS-COUPLED TANK-ENGINE* ON THE NATAL GOVERNMENT RAILWAYS.

By Mr. JOHN T. HOGG, *Associate Member*, of Durban, Natal.

[*Selected for publication.*]

In 1898 when traffic on the Natal Government Railways began to increase steadily, there were indications that this increase would continue, and the problem of providing an engine that would haul on the worst grades 50 per cent. more load than the best existing locomotive in use on that line presented itself to the then Locomotive Superintendent, Mr. G. W. Reid. The limitations imposed were:— 3 feet 6 inches gauge, grades of 1 in 30 compensated for curves of 300 feet radius, Fig. 3 (page 371), the weight on any axle not to exceed 14 tons, 78-lb. rails, and a construction gauge not exceeding 13 feet 6 inches above rail, and 9 feet between platforms.

Various objections were put forward when the design of the engine was submitted for consideration, and doubts were expressed as to sufficiency of boiler power, and to probable safeness in rounding curves; indeed it was shown on paper that the proposed engine, on account of length of wheel-base, would be deflected laterally more than twice the distance which a former type of engine had to negotiate, and would exert a correspondingly greater effort on the outer rail or on guard rail when traversing a curve.

* For other trials of this type of engine *see* Central South African Railways Locomotive Department Report for 1904, by P. A. Hyde, which contains an account of trials of similar engines compared with the same type converted to an 8-wheels-coupled engine. *See* also Report of Engine Trades of South Africa, by Ben. H. Morgan, 1902. (Secy. I. Mech. E.).

The engine is illustrated in Plate 13. The principal dimensions are :—

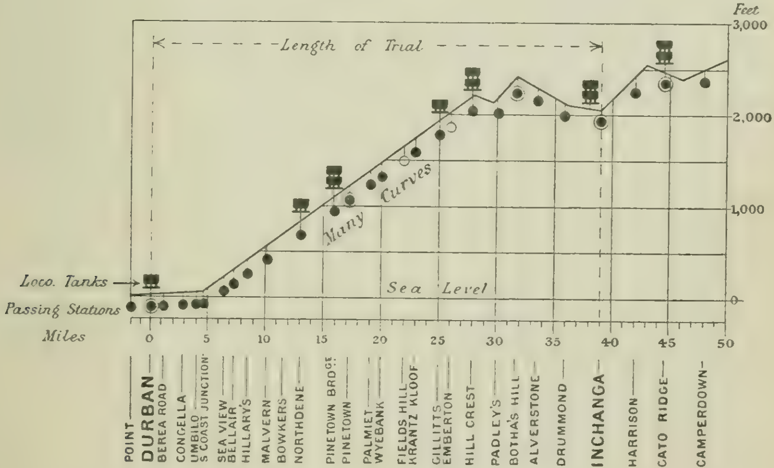
Cylinders	19 inches by 27 inches.
Wheels (coupled)	3 feet 9 inches diameter.
,, (bogie)	2 feet $1\frac{1}{2}$ inches diameter.
Boiler (outside diameter)	4 feet $10\frac{1}{2}$ inches.
Tubes	287 red metal, $1\frac{3}{4}$ inch external diameter, 11 W. G., 10 feet 4 inches long.
Heating Surface	Firebox 134·79 square feet; Tubes 1358·71 square feet. Total 1493·5 square feet.
Grate area	21·15 square feet.
Boiler pressure	175 lbs. per square inch.
From leading bogie axle to trailing bogie axle	30 feet 6 inches.
Fixed wheel-base (flanged wheels)	8 feet 4 inches.
Length of frame	34 feet 6 inches.
Total length over buffers	37 feet 6 inches.
Extreme width (footplate)	8 feet 3 inches.
Centre line of boiler from rail	6 feet 10 inches.
Chimney from rail	12 feet 6 inches.
Tank capacity	1880 gallons.
Coal capacity of bunker	4 tons.
Weight of engine (empty)	52 tons 1 cwt.
,, ,, ,, (ready for road)	68 tons 17 cwt.
Tractive force, taking M. E. P. as 75 per cent. of gauge pressure	28,374 lbs.

The valve-motion is of the Allan straight-link type, reversed by hand-wheel and screw gear. Slide-valves of the Richardson balanced type are placed in separate steam-chests between the frames on the sides of cylinder castings. The bearing for the large end of the connecting-rod is turned eccentric to the coupling-rod pin for the purpose of economy in working expansively, giving the piston the longest stroke that the wheel will permit, and at the same time keeping down the throw of coupling-rod. The leading bogie is controlled by two side-check springs and has 4 inches of side play in each direction, Plate 14. Difficulty was experienced in designing some of the parts; as an illustration it may be mentioned

that the equalizing pipe between the tanks had to be led back to the buffer-beam, then across under the frames; this pipe is of cast-iron of rectangular section 5 inches by 8 inches. It was deemed also impracticable to put vacuum-brake gear on the engine, therefore a single cylinder steam-brake, worked from a combination vacuum ejector, was adopted.

The load of this engine when first put to work was fixed at 580 tons, on the level, made up of eighteen eight-wheeled vehicles and van, the net weight being 360 tons; its capacity is much greater than that, but the difficulty of maintaining sufficient vacuum

FIG 3.



throughout a long train was the chief factor in deciding the question of load. The load over the worst portions of the line is 200 tons, but the actual amount varies up to 210 tons, of which 120 is paying load.

The cylinders of these engines are convertible to 20 inches by removing a $\frac{1}{2}$-inch liner or bush. No. 149 was treated in this way, and in August 1901 the author made a trip with that engine, taking 230 tons from Durban to Inchanga, Fig. 3, a very heavy section, including a long continuous rise with many sharp curves. The

engine hauled the load satisfactorily with the lever in such a position that the steam was cut off at about 59 per cent. of the stroke; but the steam-consumption in the large cylinders was too severe a tax on the boiler, and the experiment has not been repeated. The engines have certainly fulfilled expectations in the matter of tractive power. Halving a train on a bank is now quite unknown; should a train be temporarily stalled owing to greasy rails, these engines are always able to start away again with the whole train on an incline. Unfortunately neither the appliances nor the opportunities were available for going thoroughly into the different questions of the locomotive performances, and all information has been gathered from regular service trips.

Plate 14 shows the engine upon a curve of 250 feet radius. The first difficulty experienced in practice was when the engine (bunker first) was entering sidings, where the angle of the crossing is 1 in 7. Side-play was increased, and the leading wheels (flangeless) dropped inside the rail. To obviate this, 7-inch broad tyres were put on the leading wheels, and 6-inch broad tyres on trailing wheels, and an inclined plane arrangement was substituted for check springs on the trailing bogie.

A considerable amount of work has been done in the direction of strengthening the rails in the sidings and easing sharp reverse curves, with the result that the number of derailments has, during 1904, been reduced by 20 per cent. as compared with 1903; 90 per cent. of these derailments occurred at points and crossings, most of them while setting back, and have been explained as being due to the long wheel-base. The trailing flangeless wheels are forced over, and, catching on the switch rail, open the points which are worked by an ordinary tumbler or "Williams lever." Thus the following wheels drop between the switch and stock rails. This has been obviated by coning the tread of the tyre on the wheels referred to for a breadth of $1\frac{1}{16}$ inch.

The principal trouble with the boiler has been that the side-sheets of the firebox wear thin. This defect is accounted for by the flame striking them before being drawn over the brick arch. The part of the plate so affected was formerly cut out and a patch put

on; the injurious action, however, continues, and the patches fail through the rivet-holes down the front edge of the patch plate. This has led to the adoption of another device, namely putting in a patch the whole length of the firebox, thereby leaving no vertical ridge for the flame to strike, and has been entirely successful. The large surface of the tube-plate is to a great extent responsible for the trouble experienced at the joint of throat-plate, which gets into a leaky condition. The varying strains imposed on the plates during the cooling down, washing out, and lighting up, due to the top of the whole boiler being hotter than the lower portion (owing to restricted circulation) causes the throat-plate seam to leak. No trouble is experienced with the tubes or stays, with the exception of palm-stays, some of which have been found broken, another result of the conditions already described. The side-stays are of Messrs. Stone's No. 4 bronze, and not one has been found broken in any of the engines.

The following is an analysis of a Natal coal which was largely used; it shows a heavy quantity of sulphur, which, no doubt, acted harmfully on the plates.

Natal Coal for Locomotives.

	Per cent.
Moisture	1·5
Carbon	62·4
Volatile matter	23·9
Sulphur	2·5
Ash	9·7
	100·0

Specific gravity 1·363.

The wheel-flanges, particularly the driving flanges, wear excessively through working over so many sharp curves, so much so that the other parts of the engine require overhaul only when it is necessary to turn up the engine wheels. This excessive wear has been successfully checked on engine No. 182 by the introduction of a swing-link bogie in place of the original bogie with side-check springs. This modification has had a twelve months' trial, and the

alteration of the other engines in a similar manner is contemplated. The average mileage run by these engines before being taken into the shops is 42,232, the yearly train-mileage being 22,572. The cost of operating, including wages, coal, water and stores, works out at 9*d.* per train-mile, while the cost of repairs is 6·3*d.* per train-mile. It must not be forgotten that the wages of drivers and firemen on these engines are 15*s.* and 10*s.* per day respectively, and that running-shed fitters are paid 12*s.* and 13*s.* per day.

The following figures show the increased average tonnage obtained by the introduction of the ten-wheels-coupled tank-engines and larger capacity wagons :—

Year.	Tonnage.	Average.
	Leaving Durban.	Tonnage per train.
1897	219,052	62·98
1903	725,597	96·61
Increase . . .	506,545	33·63
Percentage of increase .	231·24	53·39

It has been shown that the increased haulage capacity of these engines saved the department from facing a serious block at Durban during war-time; the traffic forwarded from Durban during 1901 amounted to 515,793 tons, while the figures for the twelve months prior to the War (prior also to the arrival of these engines) was 221,281, which represented the maximum capacity of the engines then in use.

The Paper is illustrated by Plates 13 and 14, and 1 Fig. in the letterpress.

MEMOIRS.

PHILIP UNWIN ASKHAM was born in Sheffield on 7th January 1838. When a youth he was apprenticed to the firm of Messrs. John Brown and Co., of Sheffield, and on the completion of his term in 1866 he started in business with his brother, Mr. John U. Askham. The commencement was on a small scale, but the business soon grew, the chief products of the firm being that of steel manufactures and crucible steel castings. The manufacture of tramway points and crossings was added, and when electric traction was introduced, the firm came into great prominence with their productions. They were the pioneers in the construction of crucible steel points and crossings. In addition to tramway materials, the firm also turned out pulverizing and grinding machinery for cement, etc., also separators, conveyers, elevators, brewery trucks, hoppers, and sheet-iron works. Mr. Philip Askham devoted himself to the commercial side of the business, and travelled considerably. In 1903 the business was amalgamated with that of Messrs. Edgar Allen and Co., Imperial Steel Works, Sheffield, when the two brothers retired from the firm. For some considerable time he had been in failing health, and his death, which was not unexpected, took place at his residence in Sheffield, on 23rd May 1905, at the age of sixty-seven. He became a Member of this Institution in 1890.

THOMAS BROGDEN was born at Hull on 28th August 1840. He served an apprenticeship from 1854 to 1861 with the firm of Messrs. Fowler and McCollin, engineers, of Hull; and then was engaged as a journeyman in the works of Messrs. C. and W. Earles, of the same town, subsequently going to Messrs. Shaw and North, of Leeds. In 1869 he joined with Mr. J. Appleby in business as shipsmiths at Sandside, Scarborough, at the time when the fishing industry with

smacks was at its zenith. In 1893 the firm purchased a foundry and general works at Sussex Street, Scarborough, of which Mr. Brogden was business partner up to his death, which took place from heart failure on 16th March 1905, in his sixty-fifth year. He became a Member of this Institution in 1890.

ALGERNON HENRY DAVIS was born at Withington, Lancashire, on 18th May 1866. He was educated at Dulwich College, and afterwards at King's College, London, in applied science and engineering. From 1884 to 1888 he served his time in the works of the Société John Cockerill, Seraing, Belgium, and on its completion he entered the office of his father, who was agent and consulting engineer to the Egyptian Government Railways and Telegraphs and to the Port of Alexandria. In the capacity of manager of the office, he inspected machinery and engineering stores in all parts of Europe. He next became resident engineer during the erection of waterworks pumping machinery in Spain, and subsequently visited Australia and New Zealand. On returning to England he entered into business with his father in London as consulting engineers and contractors, and, on the death of his father, he obtained an appointment as assistant clerk to the Board of Management of the South Metropolitan District Schools. In October 1900 he was appointed general manager of Wells and Baths under the Harrogate Corporation, having charge of eighty wells and buildings; this position he held until his death, which took place from pneumonia, at his residence in Harrogate, on 18th March 1905, in his thirty-ninth year. He became an Associate Member of this Institution in 1902; and was a Fellow of the Royal Horticultural Society.

FREDERICK GREW was born at Norwich on 26th December 1819. He gained his early engineering experience in the factory of his father who was a cloth crape and bombazine finisher. In 1844 he went to London, and served his time in the Fairfield Engineering Works, Bow, at that time under the management of the late Mr. W. Bridges Adams, which subsequently became the locomotive and carriage works of the North London Railway. On the

completion of his apprenticeship, he was engaged as draughtsman for one year, and then went in a similar capacity to the works of Messrs. Swayne and Bovill, of Millwall. Among his contemporaries at the Fairfield Works was the late Sir Frederick Bramwell, who employed him during 1849 and 1850 in assisting in his various enterprises. In the latter year he was appointed resident engineer during the construction of the Tudela and Bilbao Railway. On its completion he became locomotive superintendent of the Madrid and Alicante Railway, and in the next year accepted a similar post on the Cadiz and Jerez Railway. Returning to England in 1856, he was appointed manager of the drawing office of Messrs. Brown, Marshalls and Co., of Birmingham, which post he held until 1859, when he went to Belgium for four years as inspecting engineer during the construction of the rolling-stock for the Varna Railway Co., Turkey. In 1867 he was appointed as assistant engineer on the Irish Railways Commission, which was created with the object of standardizing the existing gauges and rendering uniform other details of management. In his earlier years he was intimately associated with the radial axle-box for locomotives, and later on assisted his brother, Nathaniel Grew,* in designing a form of locomotive for running on ice, which was reported to have worked successfully in Russia on the River Neva, during the winter of 1861, conveying passengers and goods between St. Petersburg and Cronstadt. A model of it, shown in the Exhibition of 1862, is now in the South Kensington Museum. In 1875 he retired from active business, and resided alternately at Lee in Kent, St. Leonard's-on-Sea, and Switzerland. His death took place at his residence in Lee, on 19th March 1905, in his eighty-sixth year. He became a Member of this Institution in 1883.

Enoch Horton was born at Darlaston on 10th April 1829, and was educated at a local school. Having lost his mother at an early age, he commenced to work when he was seven years old, earning a meagre wage by making waxed hemp threads for the use of

* Proceedings 1897, Part 2, page 233.

shoemakers. After working at that industry for some time he became a blower of bellows for a Darlaston gun-lock forger. Then he obtained employment at a foundry in Spring Vale, near Wolverhampton, where he worked for three years, afterwards going to the Darlaston Green Works for a short time. Subsequently he assisted his father, as a nut and bolt forger, with whom in 1849 he entered into partnership, and thus was laid the foundation of a business which has since become one of the largest of the trade in the United Kingdom. The first works were situated in Bell Street, Darlaston, and the firm so prospered that larger premises were taken, the Old Alma Works being turned from a wire-drawing mill into a bolt and nut manufactory. The partnership was dissolved in 1864, and in 1870 the first portion of the present Alma Works was erected; the New Britannia Works, which were adjoining, were subsequently added. At the present time more than 600 hands are employed. He became a director of several industrial firms, and was chairman of the West Gloucester Water Co.; in local affairs he took a prominent part, being actively engaged on the Darlaston Highway Board, and after it was merged in the Local Board he became its chairman. He occupied the position of chairman of the School Board, and represented the town of Darlaston on the Staffordshire County Council; he was also a Justice of the Peace. Latterly his health had been indifferent, owing to weakness of the heart, and an attack of pneumonia supervening on a relapse caused his death at his residence at Bescot, near Darlaston, on 15th May 1905, at the age of seventy-six. He became a Member of this Institution in 1868; and was also a Member of the Iron and Steel Institute.

The Right Hon. Sir BERNHARD SAMUELSON, Bart., was born in Hamburg on 22nd November 1820. He was the son of a Hull merchant, and, after being privately educated, was apprenticed at the age of fourteen to a mercantile house in Liverpool. At the age of seventeen he was sent by his employers to obtain a number of locomotive engines at Warrington for exportation to Prussia. The whole of his scanty leisure was devoted to the acquisition of

mechanical knowledge, and he was rewarded by being entrusted by the firm of Messrs. Sharp, Stewart and Co., to take charge of their locomotive works on the Continent. After three years of this experience he set up locomotive works on his own account at Tours, in France, and carried them on most successfully until the French Revolution of 1848 caused him to leave the country. It so happened that at that time there was for sale, through the death of the proprietor, a small factory of agricultural implements at Banbury. This business he bought with a view of development, and thus founded the "Britannia Works," which transformed Banbury from an agricultural town to an industrial centre. At first he was his own manager, secretary, and traveller; the extension of the works, however, was rapid, the processes adopted being largely the invention of the firm. In 1853, when visiting Cleveland in connection with an exhibition of agricultural implements, he met the late Mr. John Vaughan, one of the pioneers of the Cleveland iron trade. The enormous iron industry was then unknown, but Sir Bernhard and Mr. Vaughan realized the possibilities of the district, and lost no time in getting capital together, with which they built, in the following year, three blast-furnaces near Middlesbrough, from each of which some 200 tons of iron were produced per week with a consumption of 800 tons of fuel. This was the beginning of his career as an ironmaster. By the year 1870 he had eight blast-furnaces at work, producing 2,500 to 3,000 tons of pig-iron per week.

His ambitions towards Parliament were awakened while a witness before a Committee of the House of Commons, and he determined to add political honours to his many existing interests. A vacancy for Banbury occurred in 1859, and, seeking election as a Liberal, he was elected by the narrow majority of one vote. In 1865 he was re-elected, and he sat for Banbury until 1885, when that constituency was merged into the North Oxfordshire Division, which he represented until his retirement in 1895, upon which he was created a Privy Councillor. With the advocacy of education, both elementary and technical, he was inseparably connected, and by his persistent efforts he forced the Government to action

Accordingly in 1867 he was charged with drawing up a report on the education of the industrial population both in Great Britain and on the Continent. This was published as a Parliamentary paper, and was a valuable addition to the knowledge of educational matters. He was a member of several commissions of education and kindred subjects, and from 1881 to 1884 was chairman of the Royal Commission on Technical Education. For his services in this connection he received a baronetcy in 1884. He made a report to the Foreign Office in 1867 on the renewal of the commercial treaty between this country and France, and was appointed chairman of the Railway Commission in 1873, and later was elected chairman of the Associated Chambers of Commerce. He was chairman of a Parliamentary Committee enquiring into the reform of the Patent Laws, and a member of the Royal Commission on Elementary Education, which reported in 1888. He acted as reporter to the Select Committee on the Drainage of the Thames Valley, and was associated with a great deal of parliamentary work in connection with other technical questions.

He became a Member of this Institution in 1865, and was a Member of Council during the years 1883 and 1884. He was also a Member of the Institution of Civil Engineers, President of the Iron and Steel Institute during 1883 and 1884, a Fellow of the Royal Society, and a Chevalier of the Legion of Honour. He also occupied the presidential chair of the Cleveland Ironmaster's Association, and was President of the Agricultural Engineers' Association. He took a great interest in the local affairs of Banbury, and presented to the town the buildings used for the Mechanics' Institute and the Municipal Schools. In 1860 he built and equipped at his own expense the Cherwell British Schools for the purpose of providing education mainly for the children of his workmen ; and subsequently he handed over the buildings to the new Borough Education Authority. On the formation of the Oxfordshire County Council he was elected a County Alderman, in which position he remained until his death ; he was also a Justice of the Peace for Oxfordshire. His death took place at his residence at Prince's Gate, London, from pneumonia, on 10th May 1905, in his eighty-fifth year.

WILLIAM SELLERS was born in Upper Darby, Delaware County, Pa., United States, on 19th September 1824, being a descendant of Samuel Sellers who emigrated from Belper, Derbyshire, in 1682. He was educated at a private school, built and maintained by his father and two relatives for the education of their children. When fourteen years of age he was apprenticed for seven years to the machinist's trade with his uncle, Mr. J. Morton Poole, of Wilmington, Delaware. In 1845 he took charge of the large machine shop of Messrs. Fairbanks, Bancroft and Co., in Providence, R.I. Two years later he went to West Philadelphia, and began a similar department of manufacture on his own account, and subsequently joined in partnership one of his former employers, Mr. Edward Bancroft, the firm becoming Bancroft and Sellers. Later, Mr. John Sellers, Jun., was admitted as a partner, and the firm moved to new works in Philadelphia. On the death of Mr. Bancroft in 1856, the firm became Messrs. William Sellers and Co., subsequently being incorporated in 1886. In 1868 he formed the Edgmoor Iron Co., of which he was the President. This company furnished all the iron structural material for the Centennial Exhibition Buildings in Philadelphia in 1876, and also that for the Brooklyn Bridge. In 1873 he became President of the Midvale Steel Co., Nicetown, Philadelphia, which he subsequently re-organized, and under his management became the first successful producer of material required by the Government for its steel cannon. The development of the business of the Edgmoor Iron Co. turned his inventive ability in new directions, and a long series of mechanical devices was evolved to meet the changing requirements of that business. The works were first started to make wrought-iron by mechanical puddling machinery of a new type, were subsequently changed to a bridge shop, and later a department was created for the manufacture of boilers of various kinds.

As illustrating his mechanical ingenuity, it may be noted that he was granted about ninety patents in the United States, either alone or in conjunction with others; the earliest was dated 1857, and patents were pending at the time of his death. His inventions covered a great variety of subjects—machine tools, injectors, rifling

machine, riveters, boilers, hydraulic machinery of various kinds, furnaces, hoists, cranes, steam-hammers, steam-engines, ordnance, pumps, etc. Probably the best known of his inventions is the spiral gear planer drive, in which the table or platten is moved back and forth by a multi-thread screw on an inclined shaft engaging with a rack on the under surface of the table. Of his individual achievements Mr. Sellers' name is best known in connection with the Sellers system of screw threads and nuts,* which eventually became the standard for the United States. A similar effort towards standardization had been previously made by Sir Joseph Whitworth, whose work no doubt inspired that of Mr. Sellers. During a visit to England in 1860, his attention was called by Messrs. Sharp, Stewart and Co., of Manchester, to the Giffard Injector for feeding steam-boilers. His immediate estimate of the value of the invention led him to obtain from them the American rights of the patent; and a Paper † was read by Mr. John Robinson in 1866, describing the improvements in the injector made by Mr. Sellers to obviate the necessity of adjusting by hand the quantity of water supplied to the injector. He became a Member of this Institution in 1865; he was a Member of the Iron and Steel Institute, a corresponding member of the Société d'Encouragement pour l'Industrie Nationale, and at the close of the Paris Exhibition of 1889 he received the decoration of Chevalier of the Legion of Honour. In addition to the foregoing he was a Member of the American Society of Civil Engineers, the American Society of Mechanical Engineers, and a Past-President of the Franklin Institute. His death took place at the University Hospital of Philadelphia on 24th January 1905, at the age of eighty.

William Harry Vernon was born at Leicester on 3rd August 1854, and received his education at the Great Meeting School of that town. He also attended science classes at St. Martin's Schools,

* Journal, Franklin Institute, 1864, Vol. I, page 344.

† Proceedings, Institution of Mechanical Engineers, 1866, page 266.

Leicester, and at the Midland Institute, Birmingham. He served an apprenticeship from 1869 to 1874 in the works of Mr. J. T. Harrot, engineer and machinist, of Leicester. In 1876 he entered the works of Messrs. E. Green and Son, of Wakefield, and had charge of the erection of fuel economizers in the Midlands and the South of England. In 1884 he commenced to represent the same firm over the United Kingdom, with the exception of Lancashire and London, and remained in that capacity until his death, which took place at his residence in Wakefield, from pleurisy on 24th March 1905, in his fifty-first year. He became an Associate Member of this Institution in 1896.

JOSEPH WRIGHT was born in London on 12th October 1826. His father was a coach builder and mail contractor; and as railways gradually superseded coaches, he transformed his business into that of a railway-carriage builder. The factories in London being too small for the purpose, new headquarters were made at Saltley Works, Birmingham. Mr. Joseph Wright, Jun., entered his father's office in London, and subsequently became a partner in the firm of Messrs. Joseph Wright and Sons, Birmingham, being associated with his father and with his elder brothers, Henry and Benjamin. By the retirement of the last named in 1859, he was left sole proprietor of the business, which about 1862 became the Metropolitan Railway Carriage and Wagon Co., on the board of which he had a seat for some time. He shortly afterwards moved to London. His death took place on 17th April 1905, in his seventy-ninth year. He became a Member of this Institution in 1859.

INDEX.

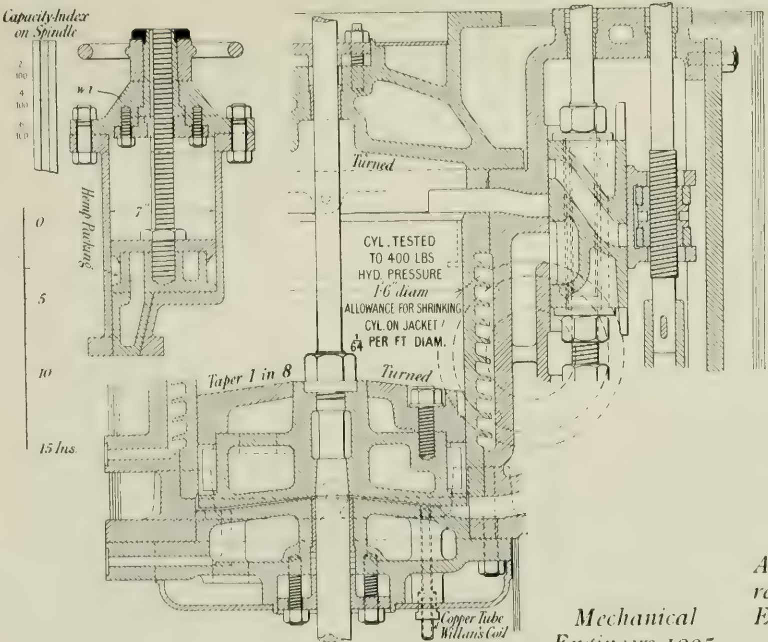
1905.

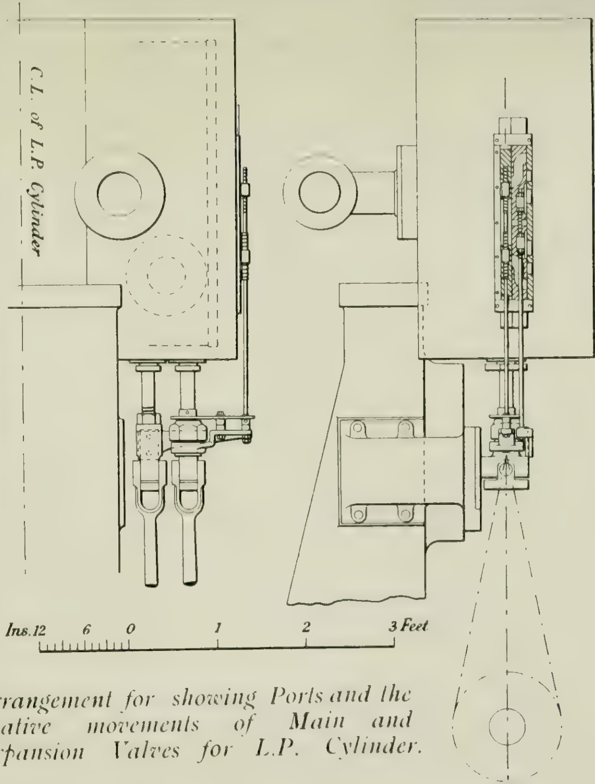
PARTS 1–2.

Montreal University Experimental Engine. (Mr. Druitt Halpin's exhibit.) Plate 6.

Clearance Pots, 2 for L.P. Cyl.

Details of L.P. Cylinder, showing Valves, Jackets, and Willans' Coil in bottom cover for boiling off any deposit water.



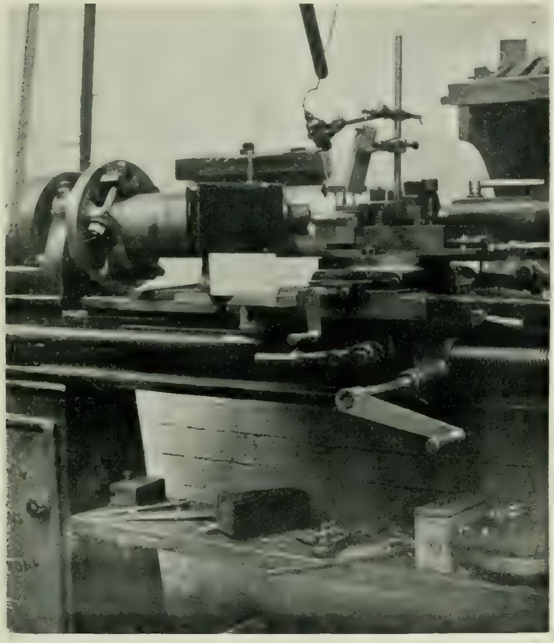


Arrangement for showing Ports and the relative movements of Main and Expansion Valves for L.P. Cylinder.

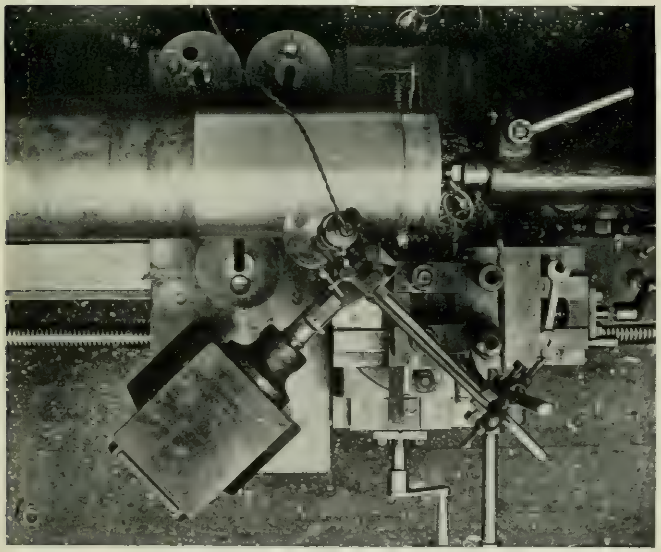
Mechanical Engineers 1905.

Lathe and Photographic Apparatus used in Experiments.

Side View.



Top View.



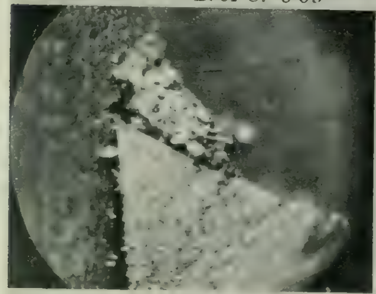
CUTTING-TOOLS IN ACTION. *Plate 8.*

Tools with varying Cutting Angle and Depth of Cut. × *6 diams.*

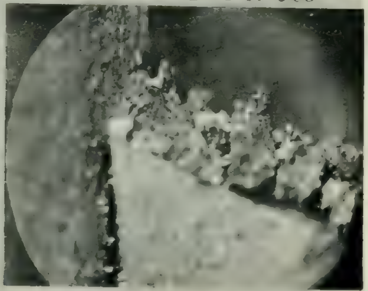
Clearance 7·5°. C.A. = *Cutting Angle.* D. of C. = *Depth of Cut.*

Cast-iron.

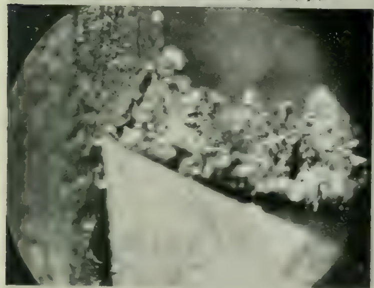
C. A. 65° D. of C. 0·05″



C. A. 65° D. of C. 0·05″

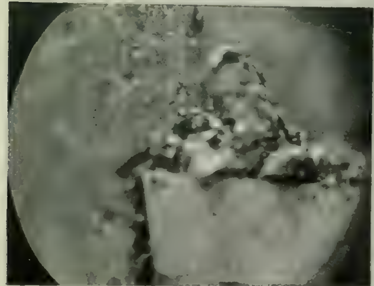


C. A. 65° D. of C. 0·075″



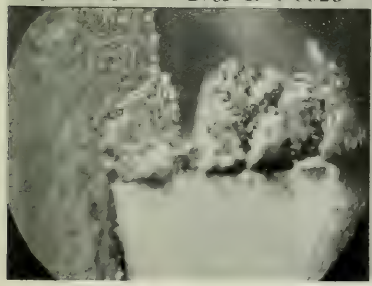
C. A. 80° D. of C. 0·075″

C. A. 85° D. of C. 0·075″

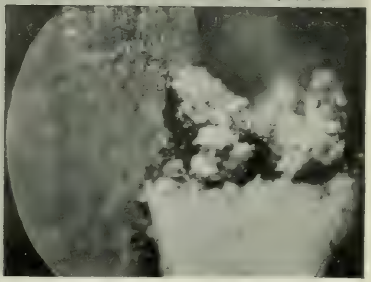


C. A. 90° D. of C. 0·075″

C. A. 90° D. of C. 0·0625″



C. A. 90° D. of C. 0·075″



Tools with varying Cutting Angle and Depth of Cut. × 6 *diams.*

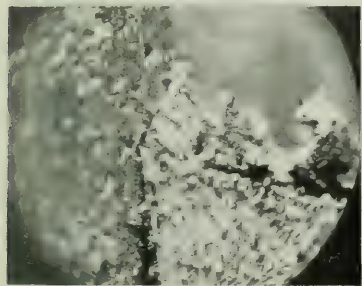
Clearance 7·5°. C.A. = *Cutting Angle.* D. of C. = *Depth of Cut.*

Cast-iron.

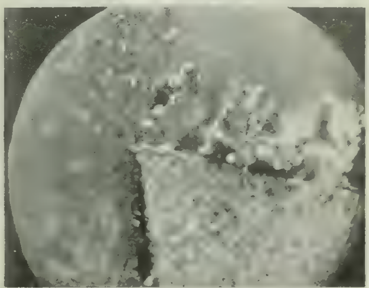
C.A. 70° D. of C. 0·025″

C.A. 70° D. of C. 0·075″

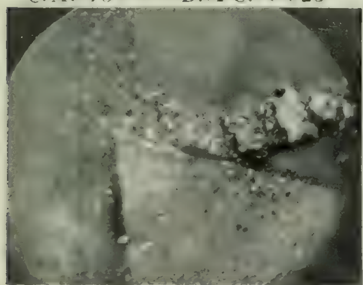
C.A. 70° D. of C. 0·05″



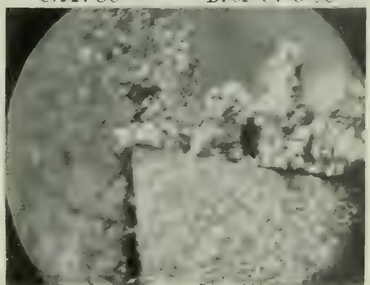
C.A. 75° D. of C. 0·05″



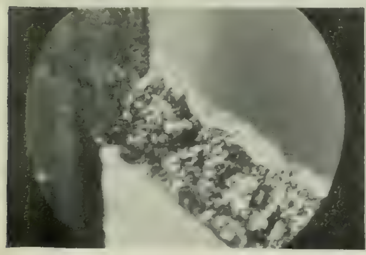
C.A. 75° D. of C. 0·025″



C.A. 80° D. of C. 0·05″



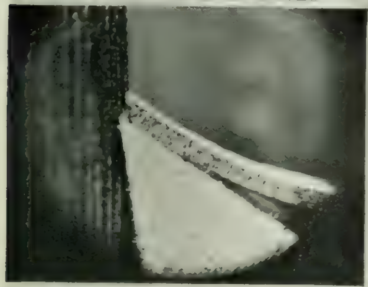
Wrought Iron. C.A. 53°



Cast Steel. C.A. 53°

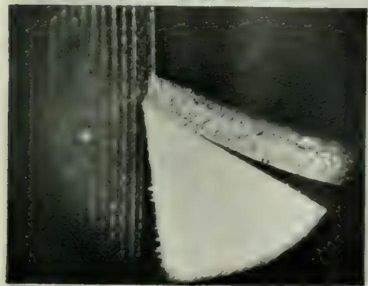
Tools with varying Cutting Angle and Depth of Cut. × 6 *diams.*
Clearance 7·5°. C.A. = *Cutting Angle.* D. of C. = *Depth of Cut.*
Mild Steel.

C. A. 55° D. of C. 0·0125″



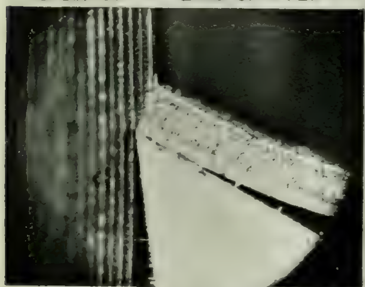
C. A. 55° D. of C. 0·025″

C. A. 60° D. of C. 0·0125″

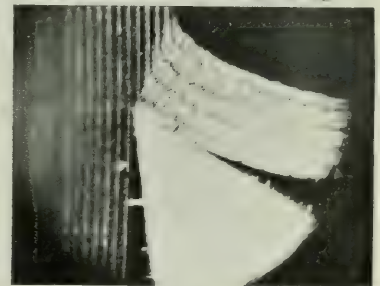


C. A. 55° D. of C. 0·05″

C. A. 60° D. of C. 0·025″

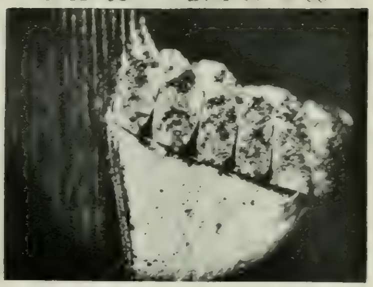


C. A. 60° D. of C. 0·05″



C. A. 65° D. of C. 0·0125″

C. A. 65° D. of C. 0·05″

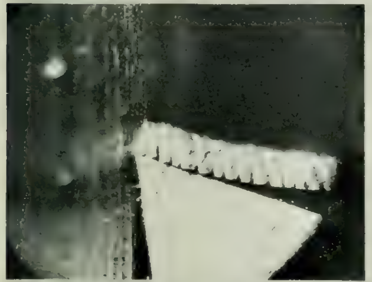


Tools with varying Cutting Angle and Depth of Cut. × 6 diams.

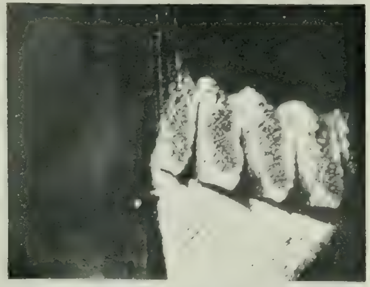
Clearance 7·5°. C.A. – *Cutting Angle.* D. of C. – *Depth of Cut.*

Mild Steel.

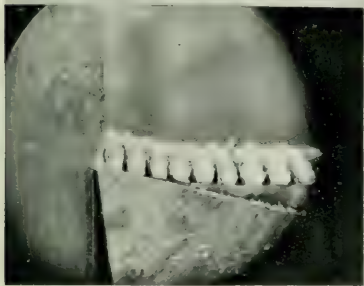
C. A. 70° D. of C. 0·0125″



C. A. 70° D. of C. 0·05″

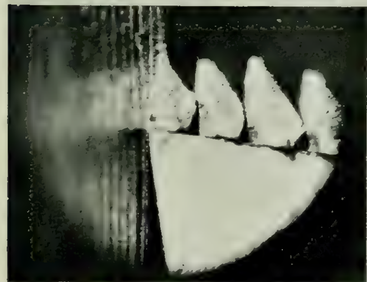


C. A. 75° D. of C. 0·0125″

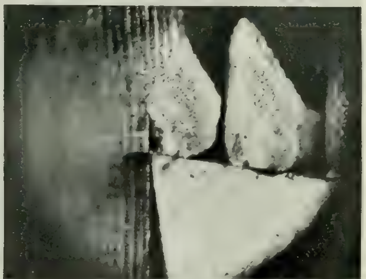


C. A. 75° D. of C. 0·05″

C. A. 80° D. of C. 0·025″



C. A. 80° D. of C. 0·05″



C. A. 90° D. of C. 0·0125″

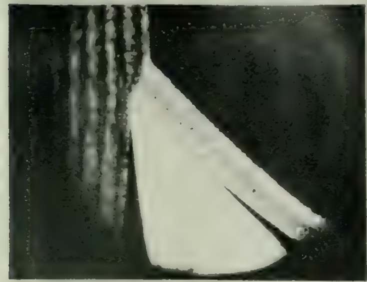
C. A. 90° D. of C. 0·05″

Tools with varying Cutting Angle and Depth of Cut. × 6 *diams.*

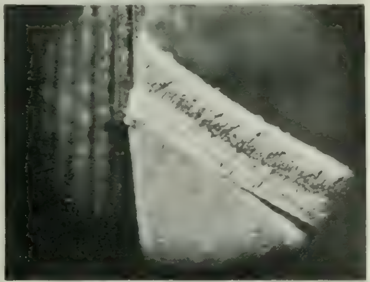
Clearance 7·5°. C.A. = *Cutting Angle.* D. of C. = *Depth of Cut.*

Copper.

C. A. 45° D. of C. 0·05″



C. A. 55° D. of C. 0·05″

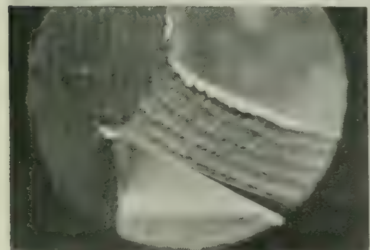


C. A. 65° D. of C. 0·05

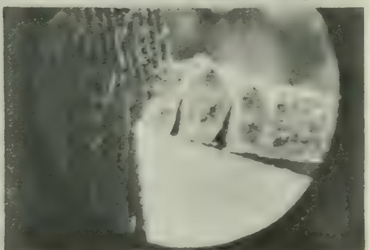
C. A. 75° D. of C. 0·05″

Gun-metal

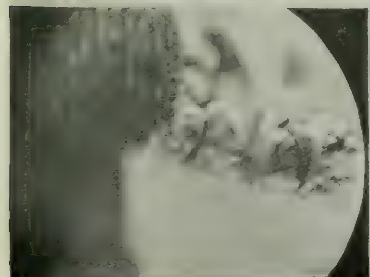
C. A. 60° D. of C. 0·05″



C. A. 70° D. of C. 0·05″



C. A. 75° D. of C. 0·05″



C. A. 80° D. of C. 0·05

TEN-WHEELS-COUPLED TANK-ENGINE.

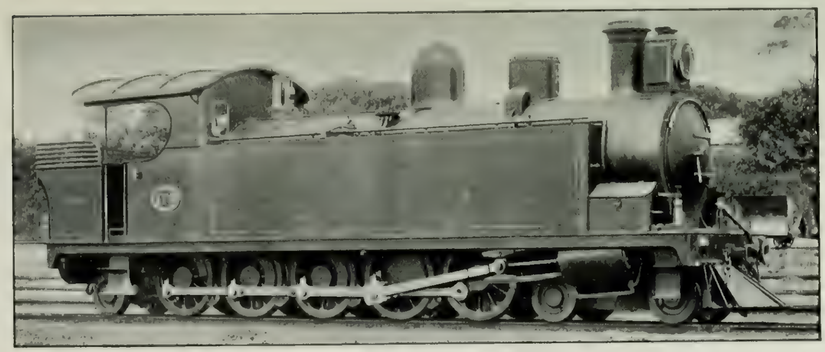


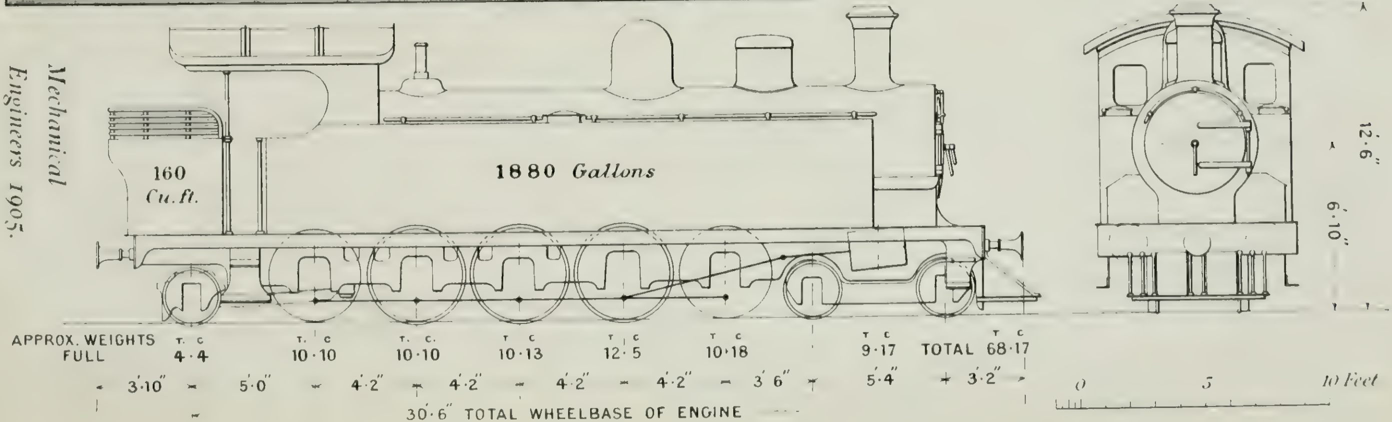
Fig. 1.

10-Wheels-Coupled Tank-Engine.
Natal Government Railways.

Boiler Pressure 175 lbs. per sq. inch.
Cylinders 19-inches × 27-inches stroke.
Wheels—Coupled 3-feet 9-inches diam.
Bogie 2-feet 1½-inches diam.
Heating Surface:—

,, ,,	Firebox	134.79	sq. feet.
,, ,,	Tubes	1358.71	,, ,,
,, ,,	Total	1493.50	,, ,,

Grate area 21.15 sq. feet.



Mechanical Engineers 1905.

Plate 13.

TEN—WHEELS—COUPLED TANK—ENGINE.

Fig. 2. *Sketch showing position of Wheels on a 250 feet Curve.*

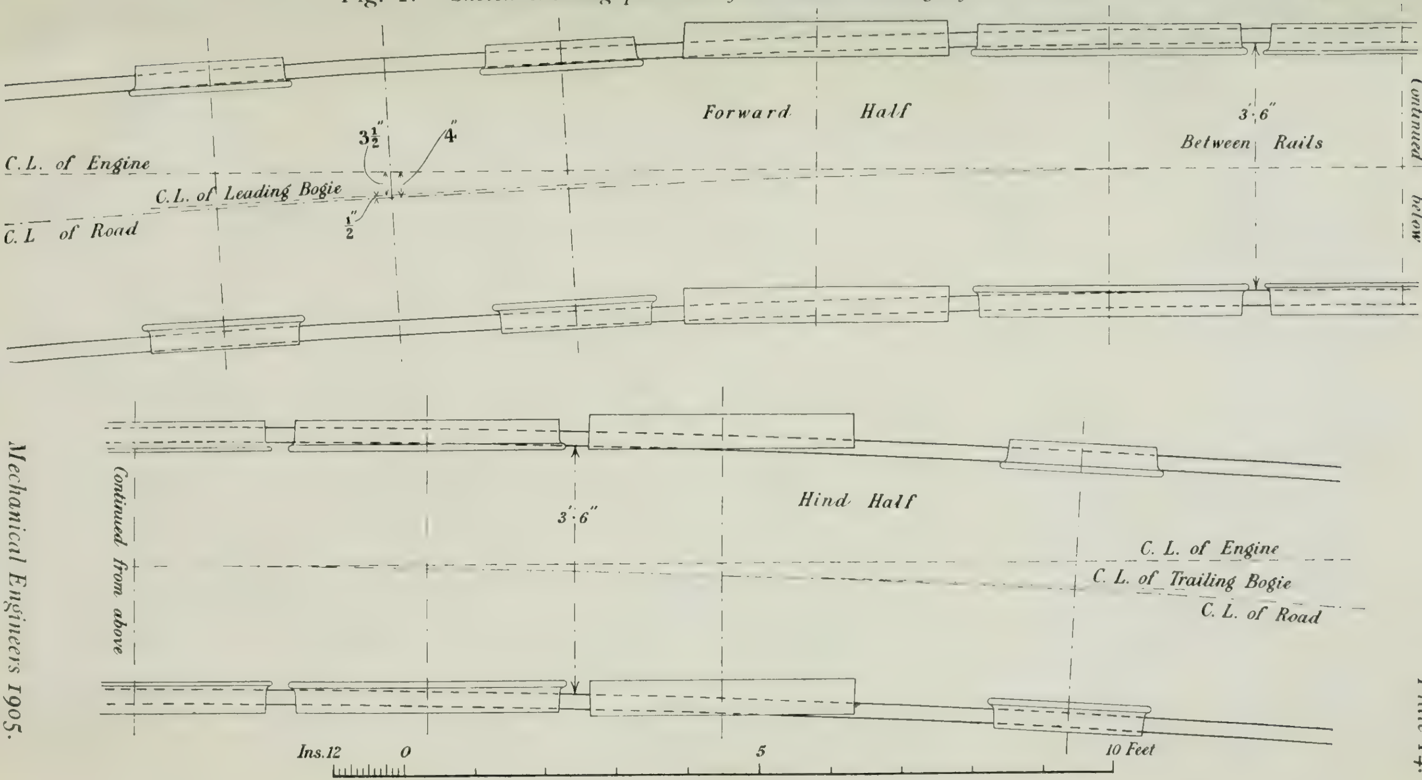


Plate 14.